(12) UK Patent Application (19) GB (11) 2 062 383 A

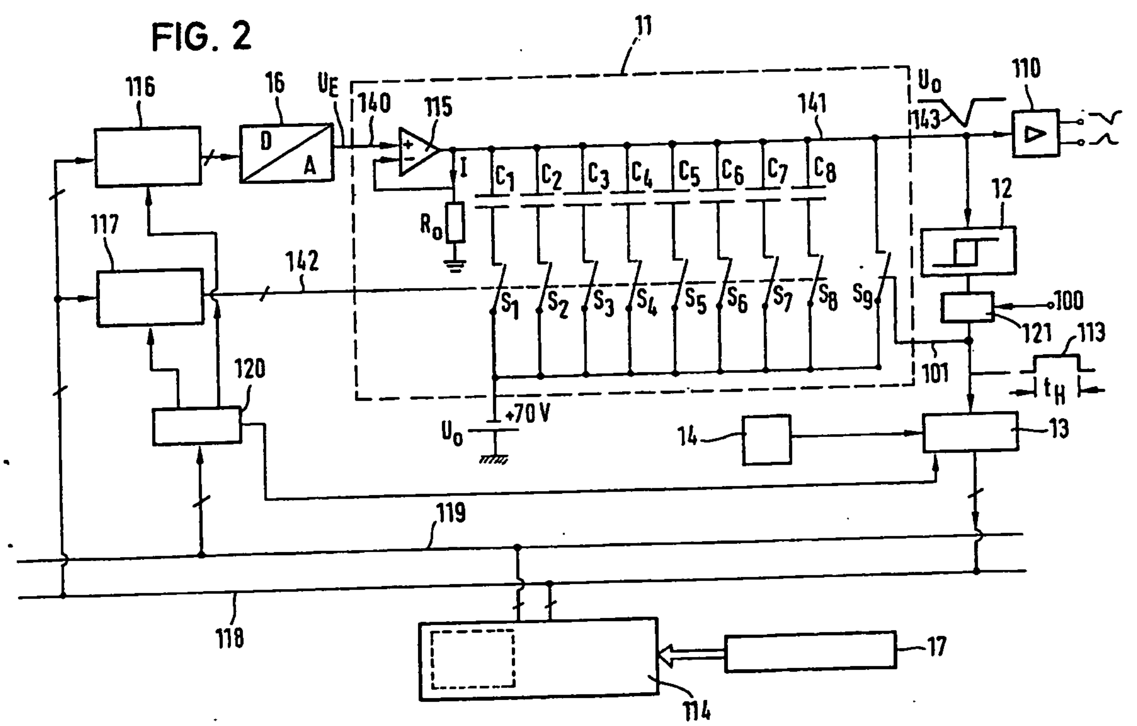
(21) Application No 8033957
(22) Date of filing 21 Oct 1980
(30) Priority data
(31) 2945200
2945202
2945201
(32) 9 Nov 1979
(33) Fed. Rep. of Germany (DE)
(43) Application published
20 May 1981
(51) INT CL³
H03J 7/06
(52) Domestic classification
H3A G5 HX LX SX
G1G 3M 4A4 6 7T EJ
(56) Documents cited
GB 1530882
GB 1409290
GB 1343108
GB 1295957
GB 1268322
GB 1168438
US 4064742A
(58) Field of search
G3U
G4G
H3A
H4T

(71) Applicants
Krautkramer GmbH,
Luxemburger Strasse 449,
5000 Koln 41, Germany,
Fed. Rep. of Germany
(72) Inventors
Peter Renzel,
Klaus Kroesen,
Werner Vermohlen
(74) Agents
Brookes & Martin, High
Holborn House, 52/54
High Holborn, London,
WC1V 6SE

# (54) Ultrasonic testing

(57) An ultrasonic testing instrument includes an ultrasonic generator, a testing head, an echo receiver and amplifier and an oscilloscopic display of the echo signals reflected from faults or inhomogeneites of the test object. In order to avoid the necessity for repeated re-calibrations of the instrument, characteristic data are entered via a keyboard 17 and corresponding digital values are stored in memory. A microprocesor 114 then sends out sequences of ultrasonic pulses of regularly varying rise/fall times and correlates the measured times with a table that permits matching the closest value to the selected data. During actual operation, the traversing time of the CRT deflection sawtooth wave is compared digitally with a calculated time and a suitable correction signal is applied to a current source 115 which modifies the charging current of timing capacitors so as to match the correct sawtooth traversing time. Additional circuitry provides for on-screen display of the position and dimensions of a detection window, textual information and other data.

FIG. 2




GB 2 062 383 A

2062383

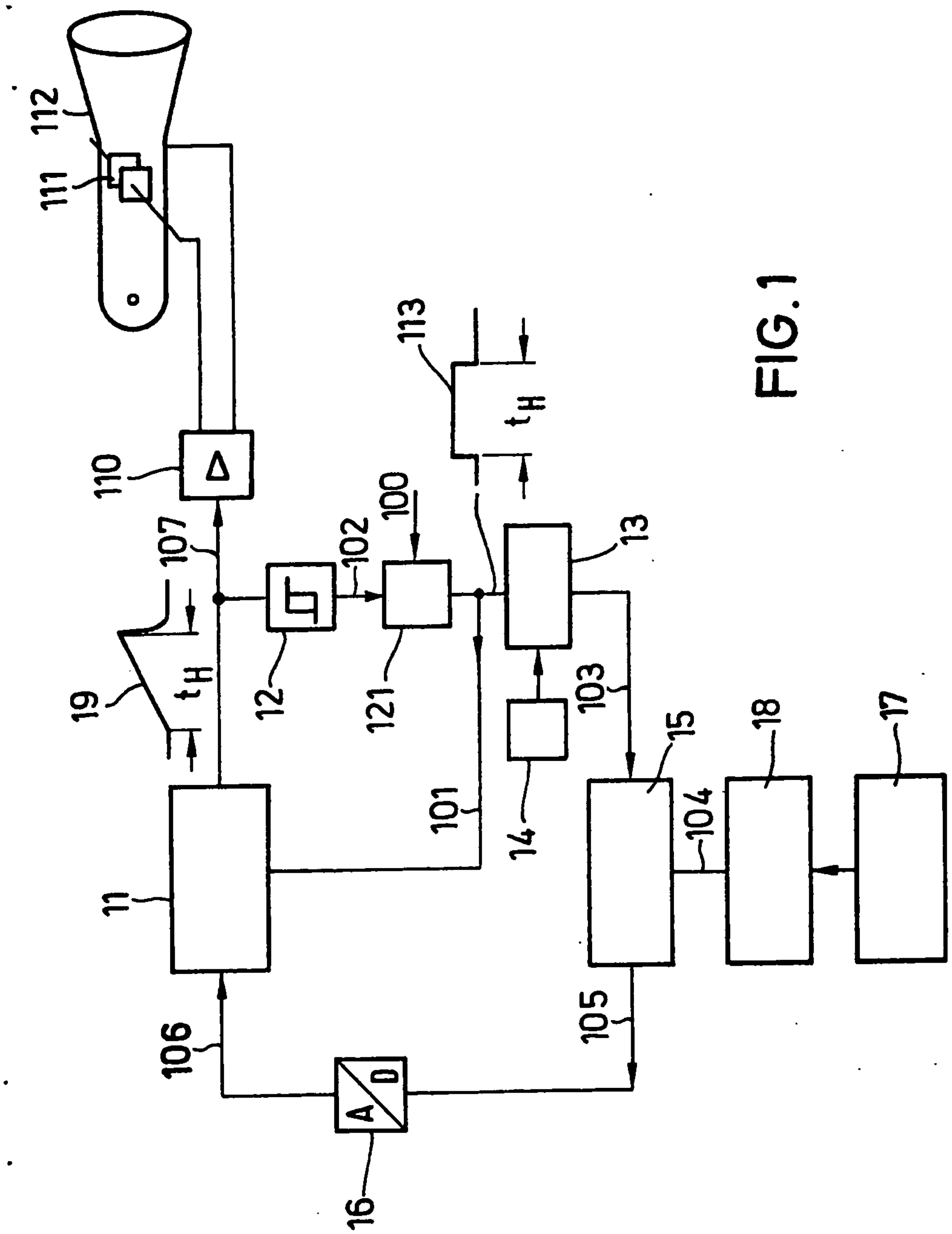
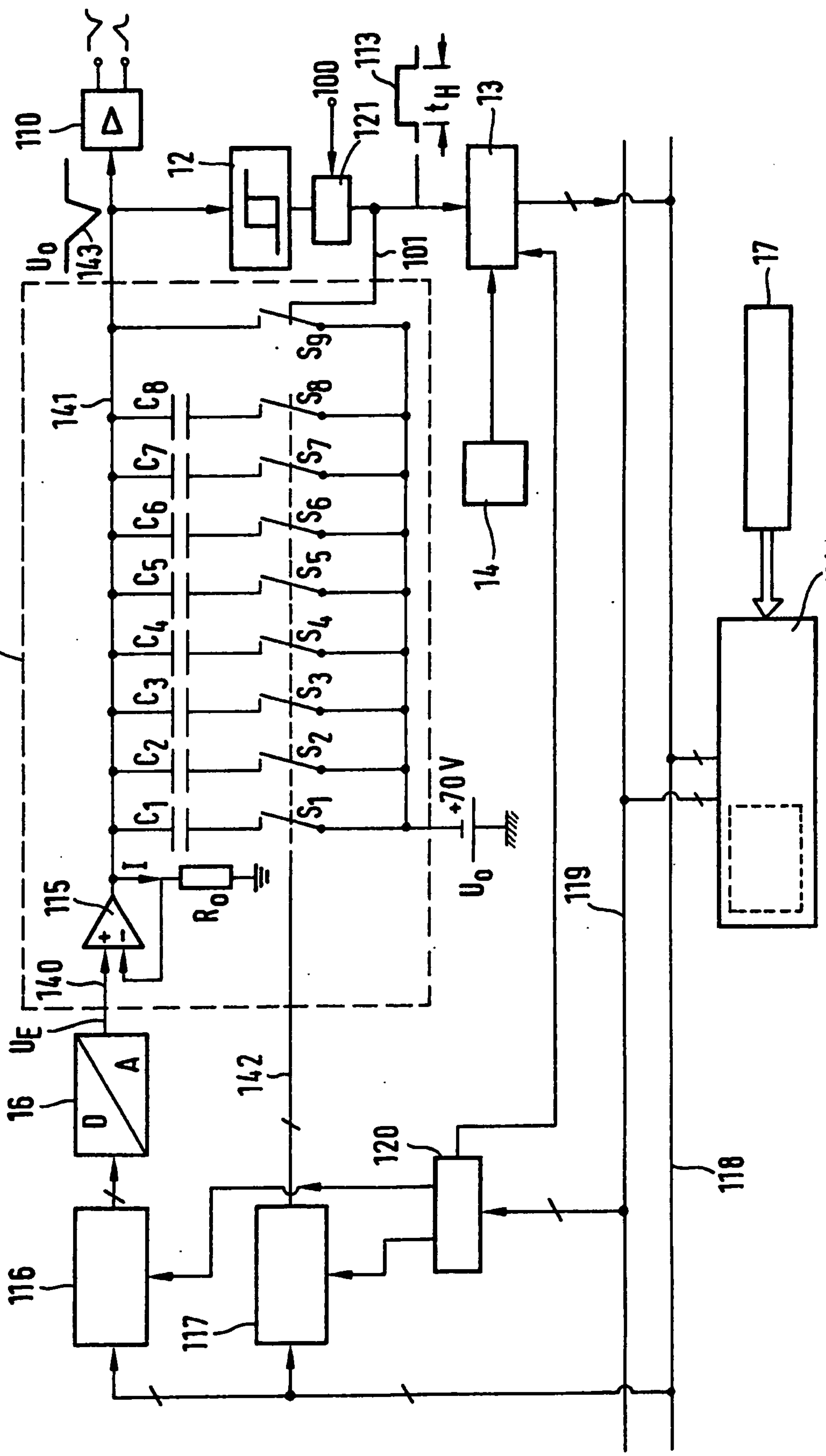



FIG. 1

FIG. 2


11
12
13
14
16
D
A
17
100
101
110
Δ
113
$t_H$
114
115
116
117
118
119
120
121
140
141
142
143
$U_0$
$U_E$
I
$R_0$
$C_1$
$C_2$
$C_3$
$C_4$
$C_5$
$C_6$
$C_7$
$C_8$
$S_1$
$S_2$
$S_3$
$S_4$
$S_5$
$S_6$
$S_7$
$S_8$
$S_9$
+70 V
$U_0$

0062383

FIG. 3

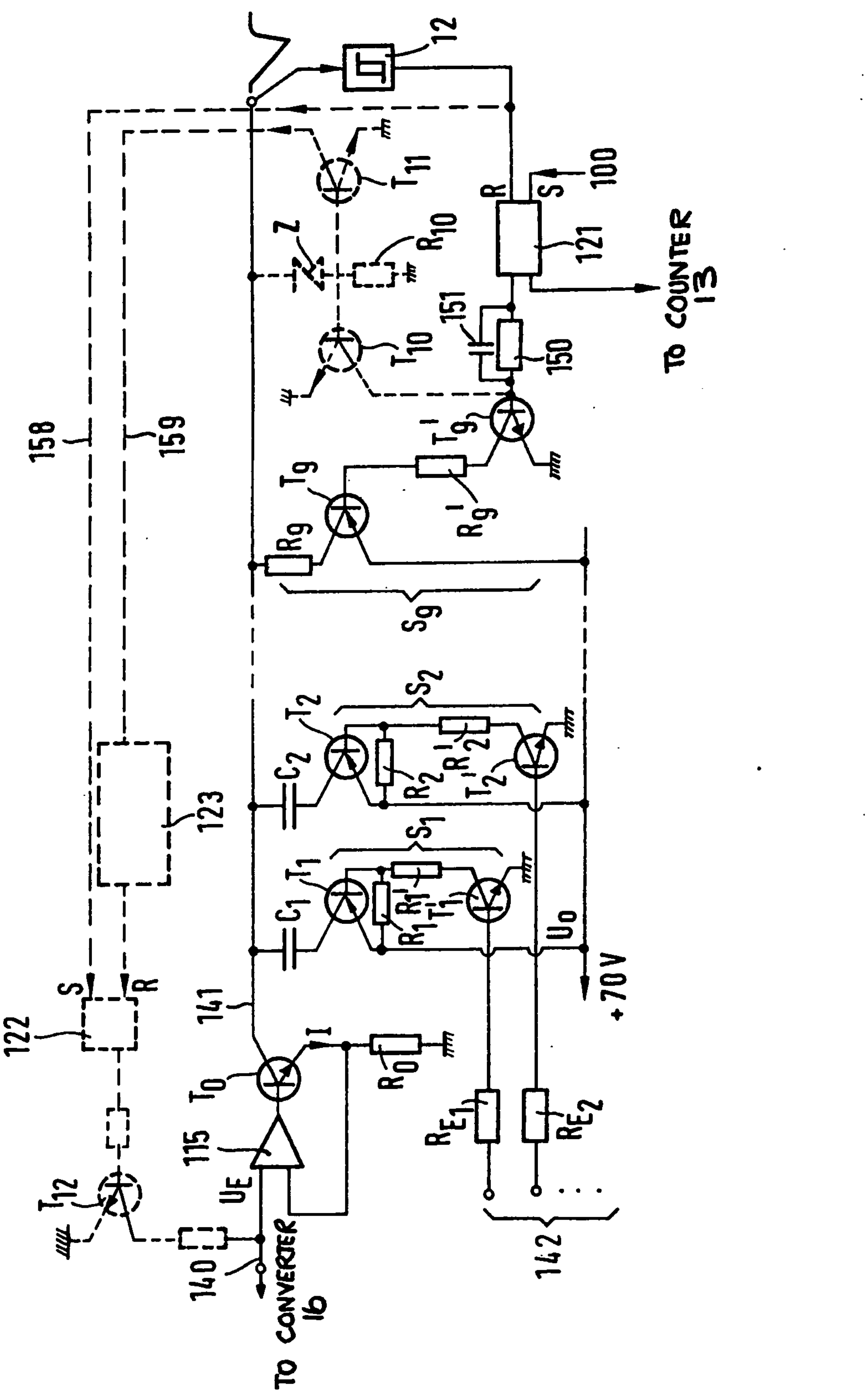


FIG. 4a

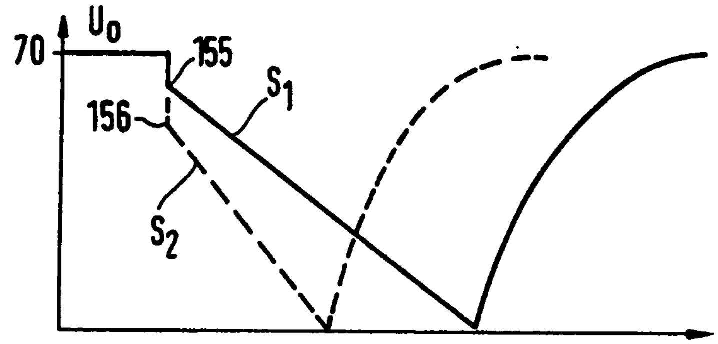
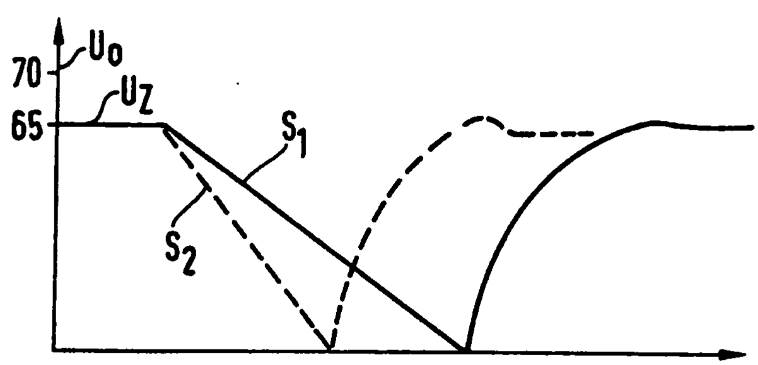



FIG. 4b



2062383

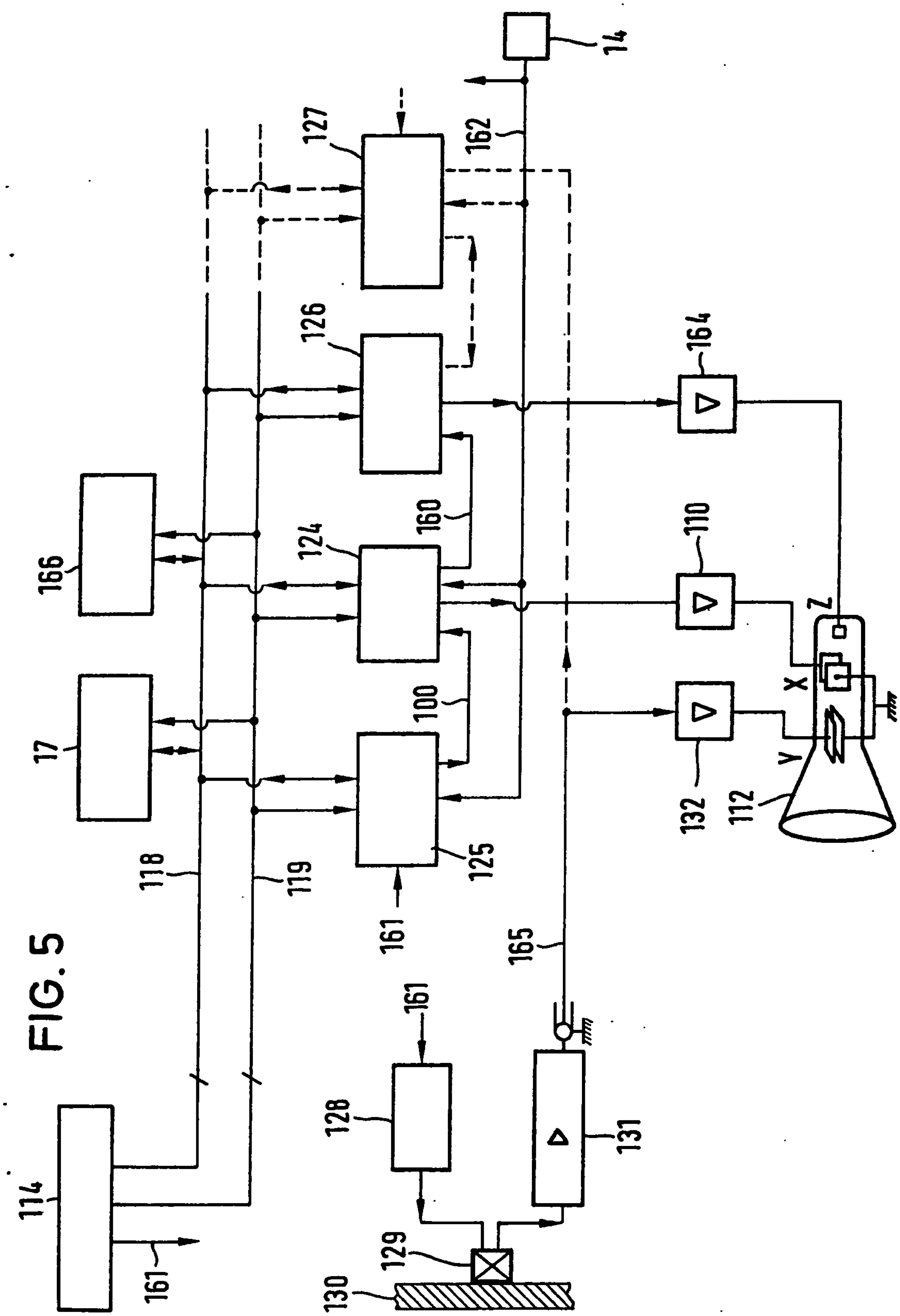



FIG. 5

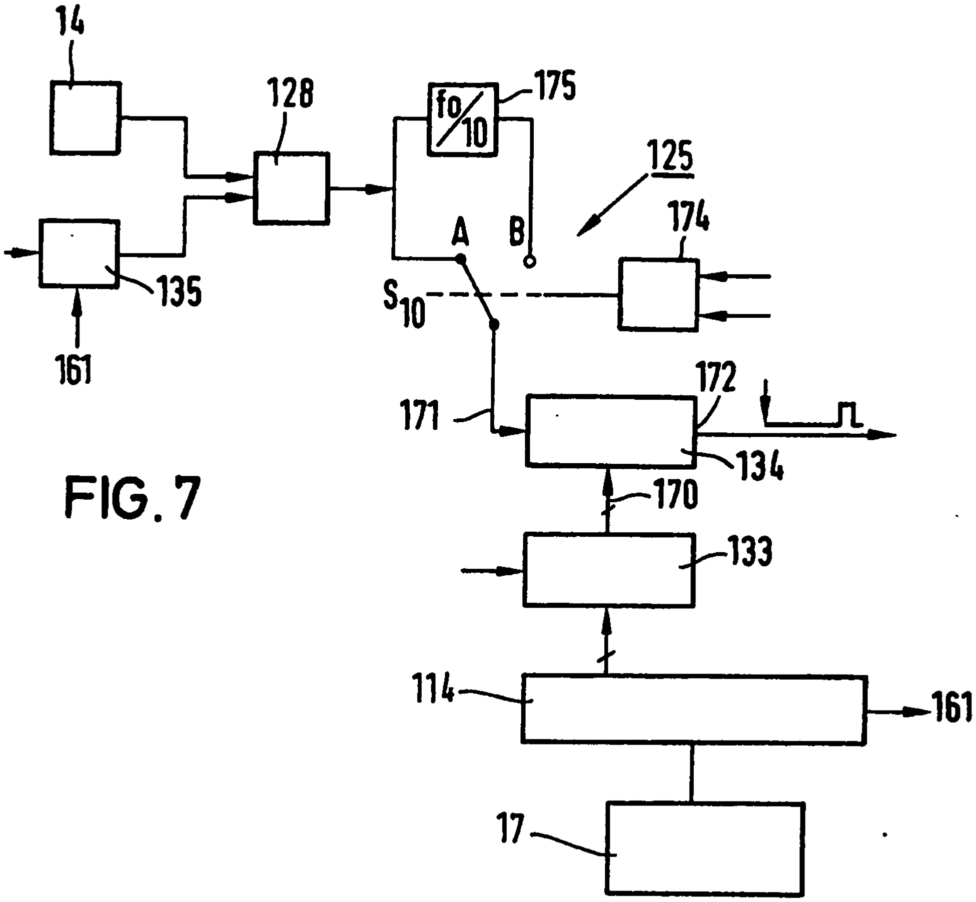



FIG. 7

FIG. 6a

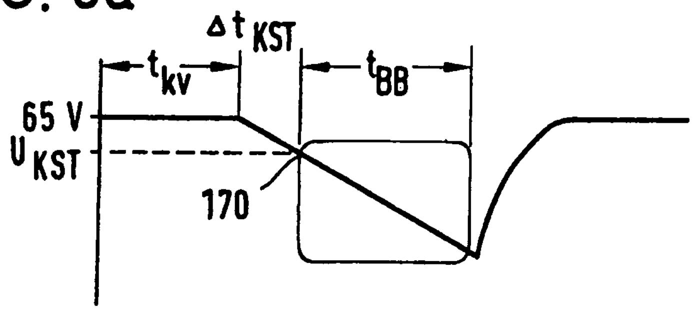
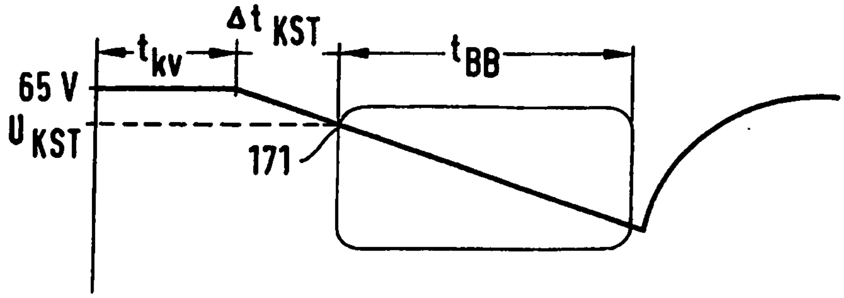



FIG. 6b



2062383

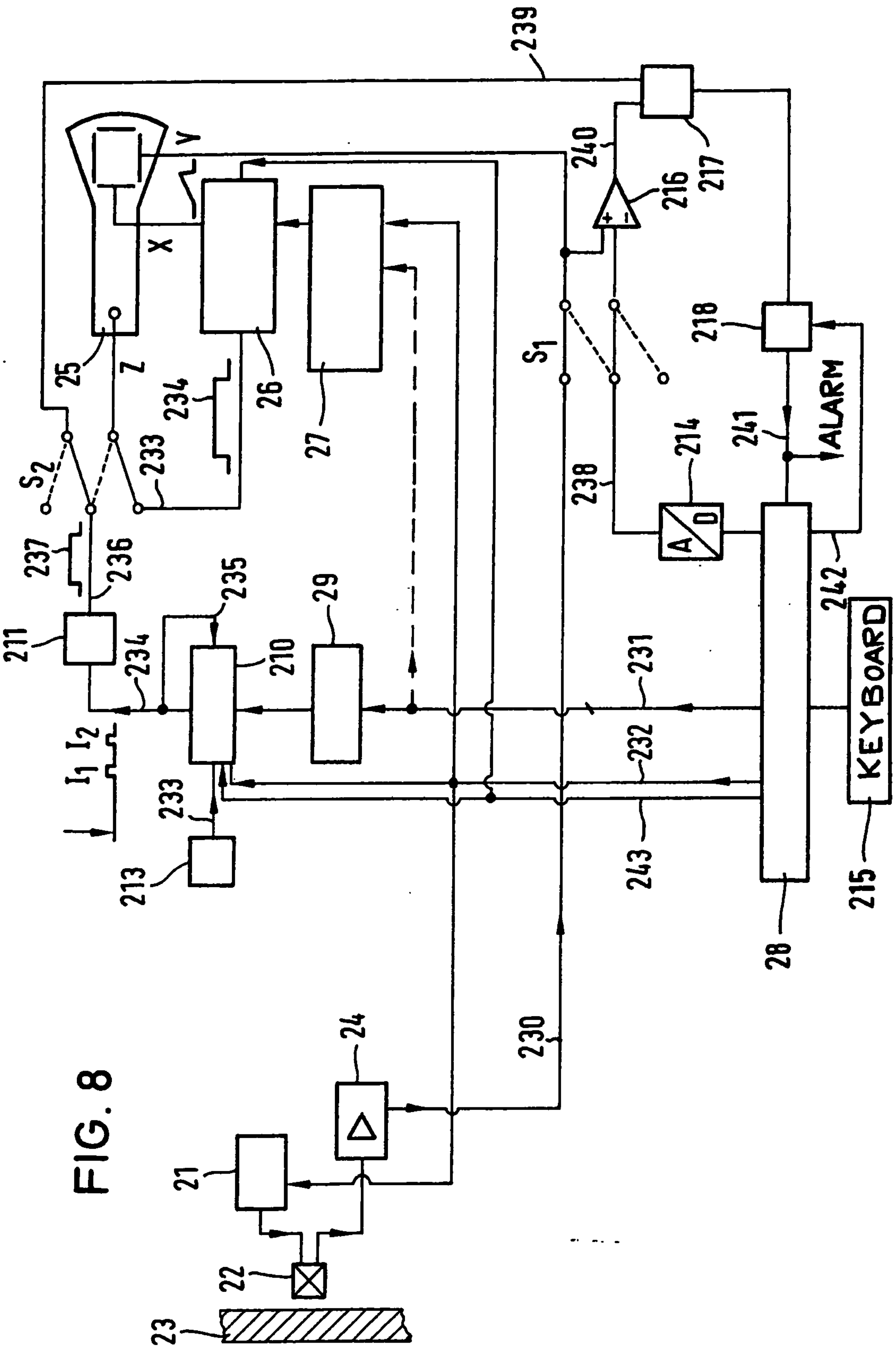



FIG. 8

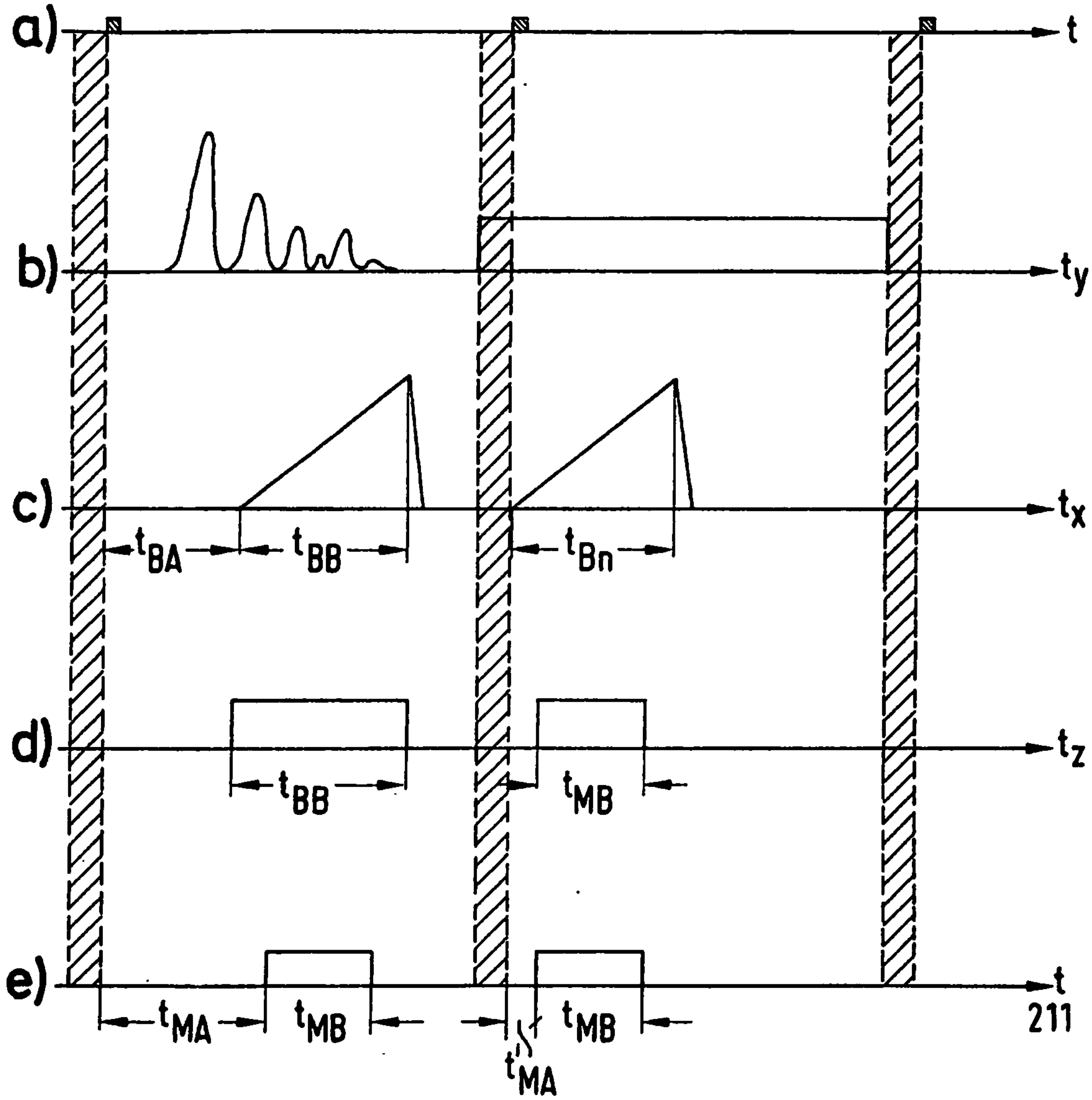
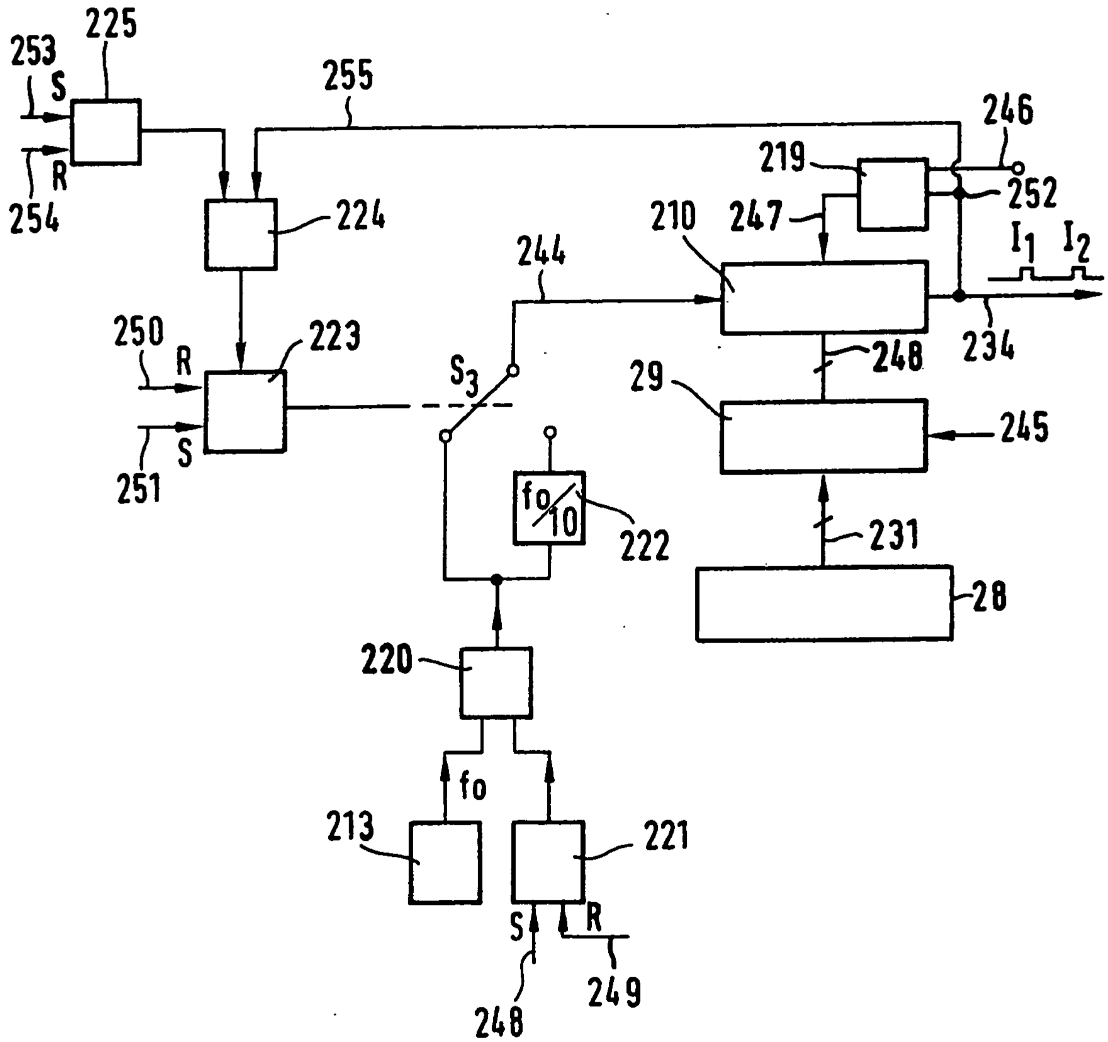



FIG. 9

FIG. 10


225
253
S
R
254
255
246
219
252
224
210
247
244
I1
I2
234
250
R
223
S3
248
29
245
S
251
fo/10
222
231
28
220
fo
213
221
S
R
248
249

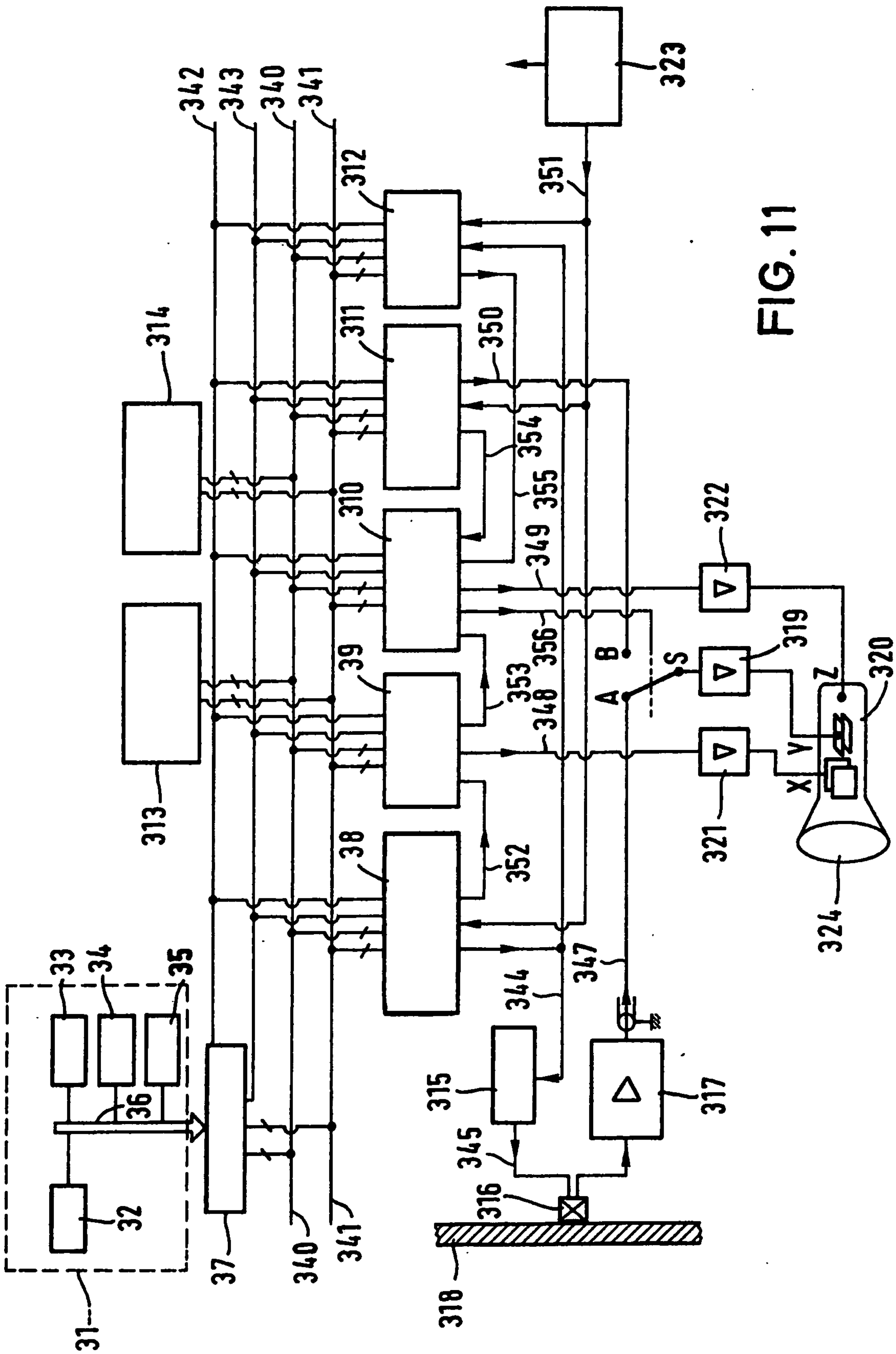

31
32
33
34
35
36
37
38
39
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
340
341
342
343
344
345
347
348
349
350
351
352
353
354
355
356
A
B
S
X
Y
Z

FIG. 11

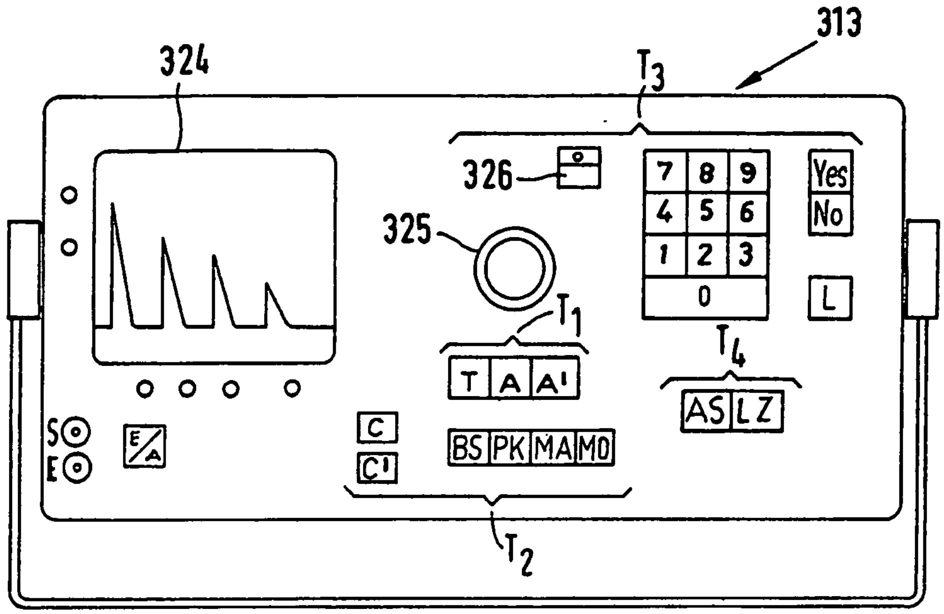



FIG. 12

| | |
|---|---|
| GATE | 1 |
| GATE BAR ONSET | 000.0 MM |
| GATE BAR WIDTH | 060.0 MM |
| GATE BAR THRESHOLD | 12% |
| COINCIDENCE | YES |
| LIGHT-UP INDICATION | YES |
| ALARM | YES |
| PEAK DETECTOR | NO |
| DISPLAY | YES |

324

FIG. 13

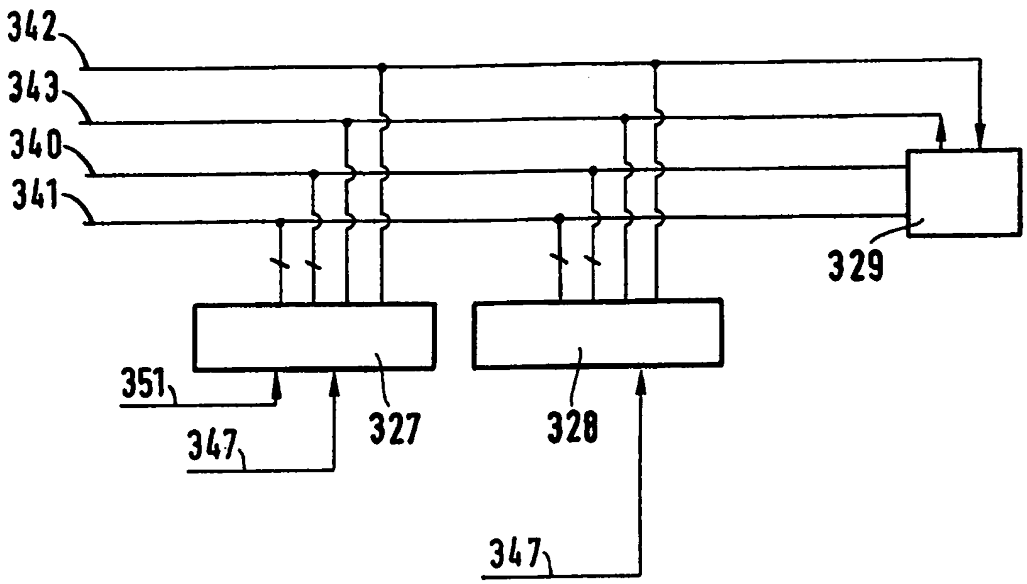



FIG. 14

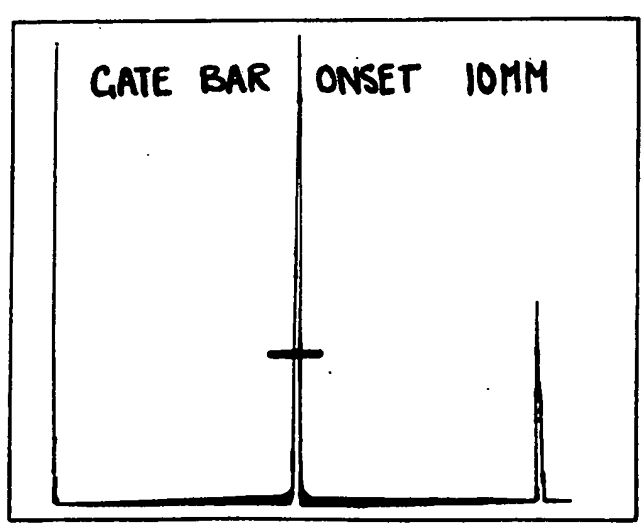



FIG. 15

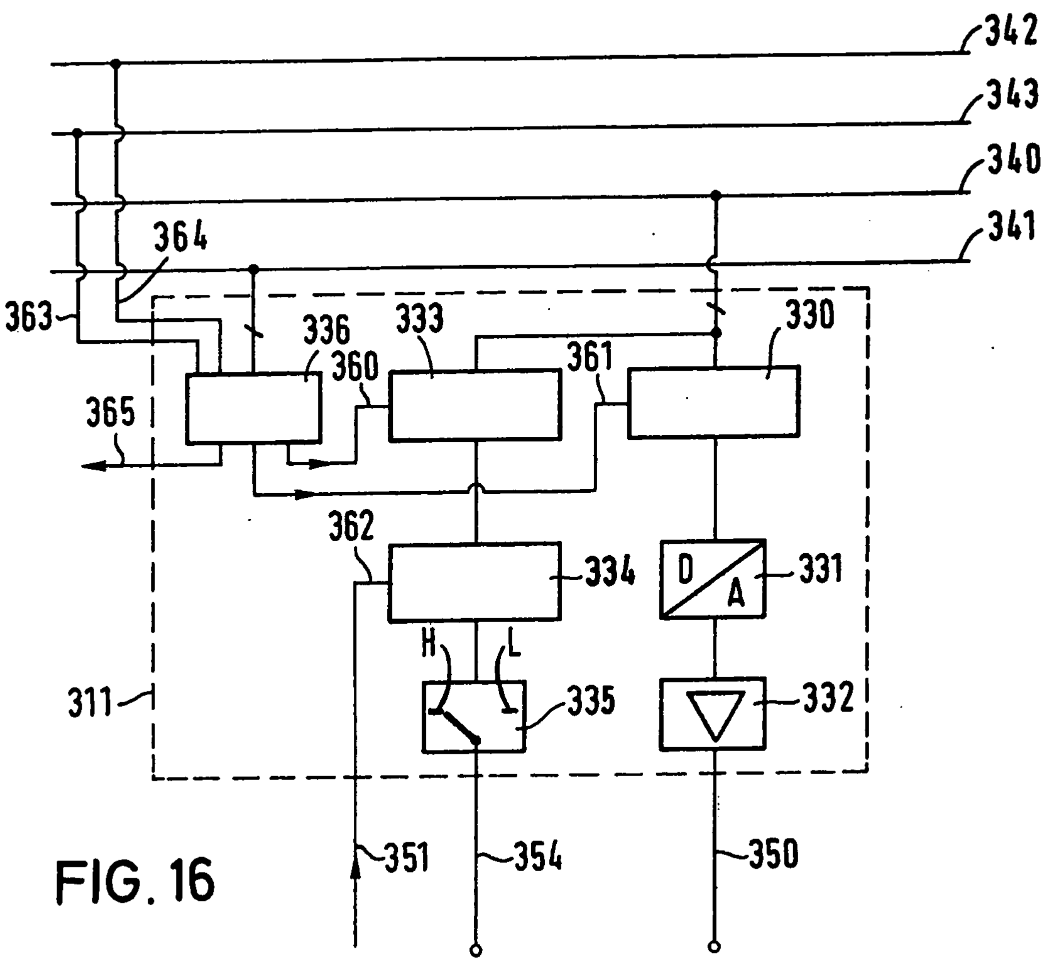

342
343
340
341
364
363
336
333
330
360
361
365
362
334
D
A
331
H
L
335
332
311
351
354
350

FIG. 16

SPECIFICATION

**Improvements in signal processing**

In ultrasonic testing, for example, echo signals received from a workpiece to be tested are converted to electrical signals and displayed as visible indications on a cathode ray tube (CRT) forming part of an oscilloscope which contains a number of control circuits for controlling the position and intensity of the electron beam of the CRT. Generally, the signal voltage to be measured is applied to one pair of deflection plates, usually called the Y-deflection plates, so that a positive signal voltage causes for example, an upward vertical deflection while a negative signal voltage causes a downward vertical deflection of the electron beam. In order to present signals as time-dependent functions, it is necessary and customary to apply a sawtooth waveform to the horizontal deflection plates, usually called X-deflection plates of the cathode ray tube. The sawtooth voltage is a uniformly increasing voltage which results in a constant horizontal deflection speed of the electron beam, i.e. in the X-direction. During the traversing time $t_H$ of the sawtooth voltage, the electron beam is deflected from left to right whereafter it returns very rapidly to its starting position.

During the return of the electron beam, the beam current is suppressed so that the return path remains invisible on the CRT.

In ultrasonic testing equipment, the ultrasonic signal transmitted into the workpiece traverses a given pathlength while the electron beam moves during the time $t_H$. Accordingly, the ultrasonic signal propagation is correlated with the movement of the electron beam; if, for example an echo signal is received by the transducer during the time that the electron beam moves to the right on the CRT, it is possible to correlate the position of the echo on the CRT with an exact location of the source of the echo in the workpiece, for example a void or fault. However, a correlation of this kind is possible with precision, only if the traversing time $t_H$ of the horizontal deflection is adjusted very precisely and can be held constant over as long a time span as desired, regardless of the long or short term stability of the various components of the apparatus. Because a full deflection of the beam up to the right-hand limit requires a given deflection voltage and because the traversing time $t_H$ is terminated when that final amplitude is attained, the slope of the rising portion of the sawtooth voltage is a function of the traversing time $t_H$. Normally, the sawtooth voltage is generated in a sawtooth generator with the aid of so-called RC elements, i.e. elements consisting of adjustable analog components, such as resistors and capacitors. The electrical characteristics of these components vary, for example as a function of age, making it necessary to perform tedious recalibrations and adjustments with the aid of calibrated test objects in order to correct the substantial errors which may occur in the traversing time of the electron beam due to long-term changes in the characteristics of the components.

Improved circuits for the generation of saw tooth voltages and the display of images on a CRT are disclosed herein in the context of ultrasonic operations, although it will be understood that the circuits are of more general applications. In the drawings, by way of example:—

Fig. 1 is a block diagram of a circuit for generating a sawtooth voltage;

Fig. 2 is a block diagram similar to that of Fig. 1 and employing a microprocessor;

Fig. 3 is a detailed circuit diagram of the sawtooth generator;

Fig. 4a and Fig. 4b are diagrams for illustrating the decrease of the voltage of the sawtooth waveform;

Fig. 5 is block circuit diagram of an ultrasonic testing apparatus;

Fig. 6a and Fig. 6b are diagrams illustrating the manner of correcting the sawtooth voltage in dependence of the selected traversing time;

Fig. 7 is a block circuit diagram of a trigger delay circuit;

Fig. 8 is a block circuit diagram of a time and amplitude gate in an ultrasonic testing instrument;

Fig. 9 is a set of diagrams illustrating various signals applied to the cathode ray tube for presenting echo signals and the gate;

Fig. 10 is a block circuit diagram similar to that of Fig. 8 illustrating additional details of the gate circuit;

Fig. 11 is an elaboration of the block circuit diagram of Fig. 5 and illustrates an ultrasonic testing instrument;

Fig. 12 is a front view of one embodiment of an ultrasonic testing instrument;

Fig. 13 is an illustration of one sample of textual information displayed on the cathode ray tube;

Fig. 14 is a block diagram elaborating the circuit shown in Fig. 11;

Fig. 15 is a block circuit diagram of the writing circuit for presenting textual information to the cathode ray tube.

Fig. 16 shows the circuit for generating the gate bar of Fig. 15.

As shown in the diagram of Fig. 1, the sawtooth generator 11 is connected by an output line 107 to a horizontal amplifier (X-amplifier) 110 which applies an amplified sawtooth voltage 19, having a horizontal traversing time $t_H$, to the horizontal (X) deflection plates 111 of a cathode ray tube 112. The exact setting of a precisely maintained traversing time (rise time) $t_H$ and thus a precisely defined slope or rate of increase of the sawtooth voltage 19 is insured by additional circuitry shown in Fig. 1, including a Schmitt trigger 12 connected to the output line 107, a flip-flop 121, a counter 13 fed by a clock pulse

generator 14, a comparator 15 and a digital-to-analog converter 16.

The flip-flop serves to initiate and terminate the sawtooth voltage generated by the generator 11 by applying thereto a gate signal 113 over the line 101. The duration of the gate signal is equal to the traversing time $t_H$ of the sawtooth signal. The gate signal is started by the application of an external trigger pulse at the input 100 of the flip-flop 121 and is terminated by the application of a signal form the Schmitt trigger at the input 102 when the (final) amplitude of the sawtooth voltage 19 exceeds the threshold of the Schmitt trigger 12, i.e. when the end of the traversing time is reached. Subsequently, the actual duration of the traversing time $t_H$ is determined in the following way: The length of the gate signal 113 is converted into a digital value by permitting the counter 13 to count pulses from the clock pulse generator 14 while the gate signal 113 is present so that the final count in the counter 13 represents the actual value of the traversing time $t_H$; this value is transmitted to the comparator 15 via a line 103.

A desired (set point) value of the traversing time $t_H$ may be selected by means of the keyboard 17. When the keys are actuated, suitable mechanism known per se, for example key switch mechanisms marketed by the firm Datanetics/Knitter, provide digital coding of the selected values according to a known diode matrix scheme, for example.

The comparator 15 compares the actual value of the traversing time $t_H$ present on the line 103 with the nominal or set-point value of the time $t_H$ present on the line 104. If these two values differ, a digital value corresponding to the difference is applied to the A/D converter 16 which puts an equivalent analog signal on the input 106 of the sawtooth generator 11. In a manner to be described below, the sawtooth generator 11 then changes the traversing time $t_H$ of the next sawtooth pulse 19. The comparison of the actual and nominal values of the traversing time takes place unitl these values are identical.

Fig. 2 is an illustration of a circuit for performing the process described above. The function of the comparator is performed by a microprocessor 114 which contains the intermediate memory 18 shown in Fig. 1 and which also performs a number of monitor and control tasks to be described in detail below. A suitable commercial microprocessor is, for example, the type Z—80, available from MOSTEK, in the category "Microprocessor Devices MK". The operating panel (keyboard) 17 is connected to the microprocessor 114. The microprocessor is connected to a preferably 8-line bidirectional databus 118 for transmitting binary coded data and is further connected to a preferably 8-line control bus for transmitting binary coded control commands. These connections are made from the output lines of the microprocessor via a known input/output circuit, for example an integrated circuit also available from MOSTEK.

The essential components of the sawtooth generator 11 are an operational amplifier 115, a resistor $R_0$ and, for example, eight capacitors $C_1$—$C_8$ which are connected to a suitable voltage source $U_0$ of approximately +70 Volts, for example, by a set of switches $S_1$—$S_8$.

The switches $S_1$—$S_8$ are preferably semiconductor switches to be further described with the aid of Fig. 3. Each of the switches $S_1$—$S_8$ is controlled by one of eight control lines 142 connected to the intermediate memory 117. A further switch $S_9$ is controlled by the gate signal 113 via the line 101; this signal is generated in the manner already described upon the occurrence of a trigger pulse at the input 100 of the flip-flop 121 at the time of release of the sawtooth pulse. The operational amplifier 115 is connected as a non-inverting amplifier and serves as a constant current source together with the resistor $R_0$. Depending on the voltage $U_E$ at the input 140 of the operational amplifier 115, its output 141 carries an associated value I whose value is determined by the value of the resistor $R_0$.

If the switch $S_9$ has been opened by the presence of a gate signal 113, any of the capacitors $C_1$—$C_8$ which are connected up will be charged by the constant current I from a discharged state in which the same voltage $U_0$ had been applied to both the top and bottom plates of the capacitors through the closed switch $S_9$. The charge on the top plates of the capacitors flows to ground through the resistor $R_0$, thereby increasing the potential difference across any capacitor which is connected to the battery $U_0$ through a closed switch $S_1$—$S_8$. As a consequence, the output line 141 carries a linearly decreasing sawtooth voltage 143 whose slope depends on the capacitance of the switched-in capacitors and on the magnitude of the constant current I. The capacitors may be said to represent a coarse setting of the traversing time $t_H$ while the magnitude of the current I, which depends on the voltage $U_E$, makes possible a fine adjustment of the traversing time $t_H$. When the signal crosses the lower threshold of the Schmitt trigger in the negative-going direction, the rear edge of the gate signal 113 automatically re-closes the switch $S_9$, causing the capacitors to discharge by placing the voltage $U_0$ at the output line 141 while the electron beam returns to its starting point. At the same time, the duration of the gate signal 113 is counted out in the counter 13 with the aid of the clock pulses generated in the clock pulse generator 14 and the value of the count is transferred to the microprocessor via the data bus lines 118, i.e. the microprocessor 114 delivers a digital value equal to the difference between the set-point value and the actual value of the traversing time. This difference value is converted into an analog signal in the converter 16, i.e. into the signal $U_E$ which causes a change in the current I and thus causes a change in the traversing time of the next sawtooth waveform. When the actual and nominal (set-point) values are found to be equal, the digital value thereof is stored in an intermediate memory 116.

A prerequisite for the fine adjustment described above is that the actual value of the traversing time is at least roughly equal to the set-point value at the beginning of the comparison. This preliminary coarse setting is obtained in that the microprocessor selects a combination of capacitors so that the joint capacitance, together with an average control voltage $U_E$, produces a traversing time which lies near the desired nominal value. The microprocessor obtains this combination by consulting a table which correlates the externally supplied settings with the appropriate combination of capacitors. A corresponding control signal then closes the correct switches $S_1$—$S_8$ and the digital value of the coarse setting is passed over the data bus 118 into an intermediate memory 117 where it is stored.

The release and loading processes in the intermediate memories 116 and 117 and in the counter 13 are initiated by signals from the decoder 120 which is connected to the control bus 119 and which is controlled by the microprocessor 114.

The above referred-to table within the microprocessor is generated by a suitable program and may be checked for accuracy from time to time in automatic fashion. For example, after the oscilloscope is turned on, the microprocessor may select an average value for the voltage $U_E$ and then connect the capacitors $C_1$—$C_8$ sequentially while constructing a table of coarse, i.e. approximate values for the traversing time of the sawtooth voltage, i.e., these values are stored temporarily. Thereafter, the nominal value of the traversing time selected on the external keyboard 17 is compared with the various values stored in the microprocessor and the closest approximate value is chosen by closing the appropriate set of switches via the intermediate memory 117.

This coarse adjustment is followed by the fine adjustment already described above. This process may take place cyclically in several stages, i.e. by successive approximation in, for example, eight steps, and may be repeated from time to time so as to insure the long-term constancy of the selected traversing time. However, preferably, the desired value of the traversing time $t_H$ is determined as follows: After the coarse adjustment, the microprocessor 114 places on the input line of the converter 16 a digital signal having the hexadecimal value 0 and stores the resulting traversing time $t_{H1}$ at the output of the counter 13; this value represents the traversing time which occurs for an adjustment current of value 0. Subsequently, this process is repeated for a signal with the hexadecimal value FF = 255 and the resulting traversing time $t_{H2}$ is also stored; this value represents the traversing time for the maximum adjustment current I. Using the values $t_{H1}$ and $t_{H2}$ and the pre-selected nominal time $t_H$, the microprocessor 114 then obtains the digital value DW which most closely approximates the desired traversing time $t_H$ on the basis of the following relation:

$$DW = 255 \cdot (1 - t_H/t_{H1}) \div (t_H/t_{H2} - t_H/t_{H1}) \qquad (1)$$

This value is transferred via the intermediate memory 116 to the converter 16 which generates a voltage $U_E$ that is used to adjust the current I in such a way as to obtain the desired traversing time $t_H$.

The derivation of the formula (1) is not a prerequisite for the understanding of the invention but the following considerations are offered.

Assuming

$$t_H = k \cdot C/I,$$

where k is a constant, C is the capacitance to be charged and I is the constant current set by the resistor $R_o$, then if

$$I = U_E/R_o \text{ and } U_E = a \cdot DW + b \text{ (a and b = constants)}$$

and using the expressions

$$a_1 = a/(K \cdot RC) \qquad b_1 = b/K \cdot RC)$$

one obtains

for DW = 0: $t_{H1} = 1/b_1$; $b_1 = 1/t_{H1}$

and for DW = FF: $t_{H2} = 1/(a_1FF + 1/t_{H1})$; $a_1 = (1/t_{H2} - 1/t_{H1})/FF$

When the values of $a_1$ and $b_1$ are substituted in these relations, formula (1) is obtained.

Figure 3 illustrates details of the circuitry, especially the construction of the electronic switches $S_1$—$S_8$ of the sawtooth generator shown in Fig. 2. These switches are constructed of per se known transistor circuits as shown. Of the switches $S_1$—$S_8$, only the first two, $S_1$ and $S_2$ are shown in Figure 3 and each of these is seen to be built up of an amplifier circuit consisting, for $S_1$, of the transistors $T_1$ and $T_1'$ and a voltage divider made up of resistors $R_1$ and $R_1'$. The base of the transistor $T_1'$ is connected via a resistor $R_{E1}$ and the line 142 to the intermediate memory 117 shown in Fig. 2. All switches $S_1$—$S_8$ are

of identical construction and each is connected, in the manner shown, to a respective capacitor, $C_1$, $C_2$ etc, the other side of which is connected to the output line 141. The function of, for example, the switch $S_1$ is that the transistor $T_1'$ becomes conductive when its base receives a voltage from the intermediate memory 117 via the control line 142, causing the transistor $T_1$ to conduct and to apply the voltage $U_o$ to the plate of the respective capacitor $C_1$ connected to its collector. The operational amplifier 115 and the resistor $R_o$ are connected to the output line 141 via a transistor $T_o$. The transistor $T_o$ serves only to minimize the effect of the constant current I on the operational amplifier 115. The switch $S_9$ which applies the voltage $U_o$ to the line 141 and hence to the upper plates of the capacitors consists basically of the transistors $T_9$ and $T_9'$ and the resistors $R_9$ and $R_9'$ and it is connected to the output of the flipflop 121 via the parallel connection of a resistor 150 and a capacitor 151. As already shown in Figures 1 and 2, the set-input of the flipflop 121 receives the trigger pulse and the reset input of the flipflop 121 is connected to the output of the Schmitt trigger circuit 12. At the occurrence of a gate signal 113 from the flipflop 121, the transistor $T_9'$ is rendered conductive causing the transistor $T_9$ to block whereas, when the gate signal 113 ends, the transistor $T_9'$ blocks and the transistor $T_9$ conducts, placing the voltage $U_o$ on the output line 141.

The circuit shown in Figure 3 also contains additional elements, not contained in the circuit of Fig. 2 and illustrated in dashed lines. These additional elements improve the effectiveness of the previously decribed circuit but elements not essential for the functioning of the circuit, e.g. resistors and capacitors, have been omitted from the figure for reasons of clarity.

The additional elements in Fig. 3 include a Zener diode Z, a resistor $R_{10}$, and a transistor $T_{10}$ which, together with the switch $S_9$, form a control loop that defines the base potential of the sawtooth voltage. Without such a control loop, the base voltages of the various sawtooth wave forms would differ due to the different conducting impedances of the transistors $T_1$—$T_8$. This situation is illustrated in Fig. 4a which shows that the base potential 155 of the switch $S_1$ and the base potential 156 of the switch $S_2$ are both smaller than the voltage $U_o$. Fig. 4b illustrates the sawtooth waveform when the additional control circuit of Fig. 3 is active. The Zener diode must be so chosen as to become conductive at a voltage $U_z < U_o$, i.e., in the present example, at a voltage $U_z = 65$ V, for example.

Fig. 3 also shows that the base of the transistor $T_{10}$ receives the voltage present at the junction of the Zener diode Z and the current-limiting resistor $R_{10}$, permitting the transistor $T_{10}$ to control the transistor $T_9$, i.e. the firing voltage of the Zener diode is stabilized in that the transistor $T_9$ blocks when the voltage on the line 141 becomes too large while it conducts when the voltage $U_o$ is too small.

The remaining additional elements shown dashed in Fig. 3 include the transistor $T_{11}$, a flip flop 122, a monostable multivibrator 123 and a transistor $T_{12}$ whose function it is to minimize the return time of the sawtooth voltage, i.e. the time during which the electron beam returns to its starting point. This circuitry is a refinement of that shown in Fig. 2 for the sawtooth generator 11. The return time will be very short if the resistance of the resistor $R_9$ is relatively small, e.g. 50 Ohm, permitting the charge of the capacitor or capacitors then connected in circuit to drain rapidly and the potential on the line 141 to return very rapidly to the value $U_o$ after the transistor $T_9$ becomes conductive.

However, if the constant current I were also permitted to flow through the transistor $T_9$ at this time, the total current would be quite high and might damage the transistor. For this reason, the constant current I is interrupted at the start of the fly-back, i.e. the beginning of the trailing portion of the sawtooth wave form, henceforth referred to as the return time. This is accomplished by passing the pulse form the Schmitt trigger which occurs when the sawtooth voltage crosses the lower threshold to the set-input S of the flipflop 122 via the line 158, causing the transistor $T_{12}$ to conduct, thereby placing the control voltage $U_E$ at the input 140 of the operational amplifier 115 at ground potential with the result that the operational amplifier 115 generates a constant output current of approximately zero value. After the Zener threshold $U_z$ is exceeded, the voltage drop across the resistor $R_{10}$, which is amplified by the transistor $T_{11}$, passes through the line 159 to the monostable multivibrator 123 which generates a corresponding short reset pulse for the reset input R of the flipflop 122 that returns the latter to its original state in which the transistor $T_{12}$ is blocked and the original constant current I is re-established by the operational amplifier 115 at a value determined by the intermediate memory 116 in Fig. 2 and by the converter 16. The effect of the additional circuitry is thus an interruption of the constant current I following the termination of the gate signal 113 until such time as the voltage on the output line 141 is equal to that defined by the Zener diode Z.

The circuitry according to the present invention, as described above, is particularly suitable for oscilloscope apparatus which already includes a microprocessor for other reasons, for example for processing the measured signals.

The circuit according to the invention may be used with particular advantage in multi-trace oscilloscopes in which each channel requires its own sawtooth waveform risetime, i.e. its own X-deflection rate. For such a case, the microprocessor automatically calculates the required coarse and fine values for the traversing times and stores them. When the X-deflection plates are switched over to another channel, the microprocessor automatically places these new values for the traversing time in the intermediate memories 116 and 117. New calibrations of the different traversing times are not required.

If the circuit according to the invention is used in ultrasonic testing equipment, the input keyboard

17 may be used to enter data regarding the desired display width (e.g. 0—200 mm) as well as the kind of material to be tested (e.g. steel) and data related to the type of testing element or testing head (e.g. a delay distance of 4 mm). In other words, the slope of the sawtooth waveform is not entered in terms of the time of traversal of the electron beam across the display but rather as the distance of travel of the ultrasonic beam in the test object (for example 0—200 mm). The propagation of the ultrasonic beam is a function of the velocity of propagation of sound in the test object and this velocity in turn relates the depth of penetration of the ultrasonic beam to the elapsed time. The data to be entered on the keyboard is thus the desired depth of inspection within the test object and the applicable velocity of propagation of ultrasonic energy. From these relations, it is possible to derive an appropriate electron beam traversing time, i.e. a time during which the test signal passes through the desired testing area. However, consideration must be given to the fact that the ultrasonic signal must first cover the distance between the piezoelectric transducer element in which it is generated and the beginning of the test region within the test object; this distance is also entered into the keyboard. The delay (pretravel) distance is actually composed of the distance between the piezoelectric element and the surface of the probe and a second distance defined by the depth at which the region to be tested begins. Accordingly, the onset of the X-deflection must be delayed by a given amount of time, called the trigger delay time, as a function of the time required for the ultrasonic beam to traverse the delay distance. This time delay is produced by a trigger delay circuit.

Fig. 5 illustrates a block diagram of the circuit for a portable ultrasonic test instrument. As already described, the microprocessor 114 is connected to the keyboard 17 via the multi-conductor data bus 118 and the control bus 119. A sweep generator 124 is also connected to the data bus 118 and the control bus 119; this trigger generator includes the sawtooth generator 11, the intermediate memories 116, 117, the decoder 120, the converter 16, the Schmitt trigger 12 and the counter 13. The trigger generator is connected to the X-deflection plates of the CRT 112 via a horizontal amplifier 110. A trigger delay circuit 125 is connected to the data bus 118 and the control bus 119 and is coupled to the sweep generator 124 via a line 100 which serves to transmit the delayed trigger pulse to the flip flop 121 in the sweep generator so as to cause the start of the sawtooth waveform.

As the electron beam is to be made visible only during its traversal time $t_H$ but is to remain dark during the flyback, a control unit 126, acting through an amplifier 164 inhibits the electron beam during that time. The control unit 126 receives a trigger signal for beam release from the trigger generator 124 via a line 160. Additional circuit elements 127, to be discussed below, may also be connected to the microprocessor 114. The clock pulse generator 14 is connected to the trigger generator 124, the trigger delay circuit 125 and the microprocessor 114 via the line 162.

The ultrasonic driving signal is generated by means of a transmitter 128 upon the occurrence of a pulse received from the microprocessor 114 on the line 161. The transmitter 128 excites the transducer 129 which emits an ultrasonic beam. Any returning echo signal is detected in the transducer 129 and converted into electrical signals which are amplified in the amplifier 131 which applies them to the Y-deflection plates of the CRT 112, causing a vertical deflection of the electron beam due to the occurrence of an echo. For example, if it is desired to test for any defects in a steel object at a depth of between 20 and 50 mm, these values are entered into the data keyboard 17 together with the velocity of sound in steel and the delay distance mandated by the type of testing head used. The microprocessor 114 then calculates the trigger delay time, i.e. the time during which the switch $S_8$ of the sawtooth generator (Fig. 2) is to remain closed. This time corresponds to the delay distance of the ultrasonic beam in the test object to a depth of 20 mm; when this distance has been traversed, the sawtooth waveform for X-deflection of the electron beam should begin. The required traversing time of the sawtooth waveform is also calculated by the microprocessor 114. These times are expressed in the form of quantities of clock pulses on the basis of a clock frequency $f_o$ which depends on the required resolution or display accuracy. For example if a resolution of 0.3 mm is required to detect faults in a steel test object, i.e. if faults of this magnitude must be reliably detected, then the clock frequency needed with ultrasonic signals whose longitudinal velocity of propagation is $c_{steel}$ (applicable for normal probes) is given by:

$$f_o = c_{steel}/2(0.3) \text{ or approx. } 10 \text{ MHz}$$

The overall trigger delay time $t_{KV}$ is the sum of the pretravel (delay) time $t_{SV}$ in the probe and the delay time $t_M$ within the test object (corresponding in the present example to a distance of penetration of 20 mm). The delay time $t_{SV}$ in the probe may be calculated from the probe delay distance $S_V$ divided by the ultrasonic propagation speed in the probe ($c_V$) while the delay time $t_M$ in the test object may be calculated by dividing the path $S_M$ within the test object (20 mm) by the ultrasonic propagation velocity $c_M$ in the test object. The quantity of pulses corresponding to the correct trigger delay time is then given by:

$$N_{KV} = 2f_o \left[\frac{S_V}{C_V} + \frac{S_M}{C_M}\right] \qquad (2)$$

The quantity of pulses corresponding to the display width, i.e. the traversing time of the sawtooth waveform, is given by

$$N_{BB} = 2f_o\,(S_{BB}/C_M),$$

where $S_{BB}$ is the depth range in the test object, e.g. 30 mm.

The pulse count $N_{KV}$ passes from the microprocessor 114 to the trigger delay circuit 125 via the data bus 118 while the pulse count $N_{BB}$ is applied to the trigger generator 124. Subsequently, the microprocessor 114 generates a trigger pulse on the line 161, whereafter the transmitter 128 starts to send out a signal. At the same time, the trigger delay circuit 125 is released and starts to count down the pulse count $T_{KV}$ which defines the trigger delay time. After the expiration of the trigger delay time, the trigger signal passes from the trigger delay circuit 125 to the sweep generator 124 via the line 100 where it causes the opening of the switch $S_9$ and the onset of the sawtooth voltage in the manner described with the aid of Fig. 2. The necessary clock pulses are provided by block pulse generator 14 over the line 162. Simultaneously with the onset of the sawtooth voltage, the electron beam current is enabled by the amplifier 164 which acts on the cathode assembly of the CRT 112; this event is produced by the control circuit 126 on the basis of a signal received over the line 160. Any echo signal received during the traversing time $t_H$ of the electron beam results in a vertical (Y) deflection of the electron beam and constitutes a fault indication in the test object. Fig. 5 includes provision for a data recording device, e.g. a cassette recorder 166 which is connected to the data bus 118 and the control bus 119 of the microprocessor 114 and serves, e.g. for recording the ultrasonic test results.

Figures 6a and 6b illustrate how the pulse count number $N_{KV}$, computed according to the formula (2), may be corrected by an improved embodiment of the invention, so as to obtain the best possible pictorial representation. This improvement is based on the following considerations. The normal starting point for the electron beam of an oscilloscopic display is a point 170, usually at the left margin of the cathode ray display tube. The electron beam occupies this point when the horizontal deflection voltage is $U_{KST}$ and has a value which is usually smaller than the base line voltage of 65 Volts of the sawtooth waveform. This situation is depicted in Figs. 6a and 6b. After expiration of the trigger delay time $t_{KV}$, defined by the pulse count number $N_{KV}$, the sawtooth voltage is released. The time $\Delta t_{KST}$ which elapses until the electron beam has reached the point 170 depends on the slope of the sawtooth waveform. As shown in Fig. 6b, if the slope is shallow, the actual image starting point 171 is reached at a later time than would be the case with a steep slope. Accordingly, it is suitable to delay the onset of the sawtooth voltage in dependence on the slope of the waveform. The delay of the trigger starting point can be derived approximately from the formula

$$\Delta t_{KST} \approx a \cdot t_{BB}$$

where a is a constant which depends on the desired image starting point and $t_{BB}$ is equal to the traversing time $t_H$ of the electron beam and corresponds to the time during which it is possible to observe the beam on the screen in its motion from left to right, for example. The resulting corrected pulse count number is then

$$N'_{KV} = N_{KV} - aN_{BB}.$$

Fig. 7 is a block diagram of a trigger delay circuit 125. The pulse count number $N_{KV}$ which is calculated by the microprocessor 114 on the basis of the data entered into the keyboard 17 is loaded into a register 133 and passes over a first input line 170 to a binary counter 134. The second input 171 of the binary counter 134 is connected to the output of an AND-gate 128 through a switch $S_{10}$. The inputs of the AND gate 128 are connected, respectively, to the output of the clock pulse generator 14 and an output of a flip-flop 135. A further flip-flop 174 actuates the switch $S_{10}$ between two positions A and B; in the position A, the binary counter 134 receives the pulsetrain with frequency $f_o$ whereas, in the position B, the counter 134 receives a pulsetrain of frequency $f_o/10$ after division in the circuit element 175. This selection makes possible a change of the effective image resolution, as previously described. If the trigger pulse generated by the microprocessor 114 on the output line 161 reaches the flip-flop 135, the AND-gate 128 is open and the clock pulses pass from the clock pulse generator 14 to the binary counter 134. As a result, the triggering delay number $N_{KV}$, which is stored in the counter 134 is counted down at the frequency $f_o$ or $f_o/10$, depending on the position of the switch $S_{10}$. At the conclusion of the count, the counter output 172 generates a pulse which passes over the line 100 (Fig. 5) to the trigger generator 124 and constitutes the onset of the gate signal 113 which opens the switch $S_9$ (Fig. 2) that releases the sawtooth waveform.

It is a substantial advantage of the present invention that the above described circuits make possible the calibration of the imaging area of the CRT in terms of units of length. This calibration is based on the provision of suitable traversing times of the beam, i.e. rise/fall times of the leading ramp of

the sawtooth waveform which serves as the horizontal deflection voltage (time base voltage). A direct calibration of this kind has not heretofore been possible in testing instruments because the known instruments did not possess the necessary long-term stability of timing components so that the agreement between the selected values of the traversing times and the actual values differed in unpredictable ways and could become substantailly different over the course of time. In order to counteract these defects in the known apparatus, it has become customary to re-calibrate the CRT displays by conducting tests on test objects of known dimensions. This kind of re-calibration, which is relatively time-consuming and which must be repeated from time to time can now be avoided due to the features of the present invention. According to the invention, any imaging region may be pre-selected on the keyboard and will be maintained exactly by the continuous comparison of the nominal value and the actual value of the effective beam traversing time.

As previously described, the invention permits the representation of a particular range within the test object by causing the triggering of the sawtooth signal, i.e. the start of the CRT image field, after a given holding or trigger delay time has expired and it further permits a selection of the length of the imaging region on the basis of the sawtooth rise/fall time, i.e. the beam traversing time.

It may be desirable to provide for an automatic indication of the occurrence of echo signals which are produced by faults within a given depth range in the test object. Such automatic indication is also possible according to a further feature of the invention to be described below. This feature is a so-called time and amplitude gate which defines and displays a "gate-bar" on the CRT screen. Any echo signal whose amplitude is greater than the vertical position of a bar display and which occurs within its horizontal limites, i.e. its width, is automatically recognized and may serve to initiate an alarm or other action. The vertical and horizontal positions of this gate-bar and its width should, advantageously, be selectable. The gate-bar may be displayed by the electron beam between successive displays of the other signal data on the screen.

Fig. 8 again illustrates an ultrasonic testing instrument which includes a transmitter 21 for producing the sound-generating drive signal for the transducer 22, an amplifier 24 for receiving echo signals detected by the transducer 22 and associated elements to be described. The echo signals received from the test object 23 are converted into electrical pulses and amplified by the amplifier 24; they pass over the line 230 to the vertical (Y) deflection plates of the CRT 25 to cause the vertical deflection of the electron beam in known manner. The horizontal timing signal, i.e. the sawtooth voltage, is produced, in the manner already described, by the trigger generator 26 and corresponds to the range of interest within the test object. The necessary holding time, i.e. the time which must elapse between the onset of the ultrasonic signal and the release of the sawtooth waveform, is determined in the trigger delay circuit 27 as also already described.

The microprocessor 28 passes the corresponding trigger pulse over the line 232 to the transmitter 21 and to the trigger delay circuit 27. In this illustration, the data and control buses for transmitting the data and pulse count numbers among the various circuits have been omitted for clarity. During the traversing time of the beam, the trigger generator 26 places a signal 234 on the line 233 which serves to enable the cathode assembly of the CRT and provides for the display of signals thereon.

The horizontal distance $S_A$ defining the start of the gate-bar (time gate) and its width $S_B$ are produced by the microprocessor 28 whose output line 231 is connected to a register 29 which is followed by a counter 210 connected to a flip-flop 211.

Let it be assumed that the various data items relating to the characteristics of the testing head, as well as the delay distance $S_V$ of the ultrasonic signal in the probe, the velocity of sound $C_V$ in the probe and the velocity of sound $C_M$ in the test object are all known and are available as digital values within the assigned memories of the microprocessor 28. If the operator now selects the desired gate-bar constants, i.e. the starting position $S_A$, the width $S_B$ and the vertical position of the gate-bar (amplitude) by entering these data as e.g. lengths in millimetres or percent of CRT height, the microprocessor 28 computes the corresponding internal data items on the basis of a stored program. These internal data items are previously referred to pulse count numbers of the type N, in this case a number N, which defines the onset position of the gate-bar and $N_{MB}$ which defines the width of the gate-bar.

The clock frequency $f_o$ depends on the desired resolution, i.e. on the precision required in the image. As already discussed in connection with the overall image width, an image resolution of 0.3 mm in a test object made of steel in which the speed of propagation of longitudinal ultrasonic waves is $c_{steel}$ requires a clock frequency given by

$$f_o = c_{steel}/2(0.3\text{ mm})$$

or approximately 10 MHz.

If $t_A$ is the time up to the occurrence of the gate-bar, i.e. the time which is the sum of the delay times in the probe and the test object, then the pulse count number defining the horizontal position of the gate-bar is given by

$$N_{MA} = 2f_o\,(S_V/C_V + S_A/C_M)$$

where $S_V$ is the delay distance in the probe;
$C_V$ is the velocity of sound in the probe;
$S_A$ is the delay distance in the test object;
$C_M$ is the velocity of sound in the test object.

The pulse count number defining the bar width is given by

$$N_{MB} = 2f_o\,(S_B/C_M)$$

where $S_B$ is the width of the bar in units of length.

The calculated pulse number $N_{MA}$ is loaded into the register 29 via the line 231 and is passed into the counter 210. Subsequently, the pulse number $N_{MB}$ is also transferred to the register 29 where it stands ready to be passed to the counter 210. If the line 232 now receives a new trigger pulse from the microprocessor, this pulse opens the input 233, causing the contents of the counter 210 to be counted down by the signal train from the clock 213, at the frequency $f_o$. When the count is complete the counter output 234 carries a first pulse $I_1$ which sets the flip-flop 211.

The pulse $I_1$ is also passed to the load inputs 235 of the counter 210 and enables them for receiving the pulse number $N_{MB}$ which is immediately counted down, whereafter the counter output 234 carries a pulse $I_2$, which resets the flip-flop 211, causing a square pulse 237 to be generated at the output 236 of the flip-flop 211. The ultrasonic signal and the gate-bar are displayed alternately on the screen by the switches $S_1$ and $S_2$. For the position of these switches as shown in Fig. 8 (full lines), the ultrasonic signal is displayed and passes through the line 230 to the Y-deflection plates of the CRT 25. At the same time, this signal passes to the comparator circuit 216 whose other input is connected to the converter 214 through the switch $S_1$ and the line 238. The converter 214 transforms the digital value of the bar height into an analog voltage. Fig. 8 also shows that the two inputs of an AND-gate 217 are connected, respectively, to the output line 240 of the comparator 216 and the line 239 leading to the switch $S_2$. If the comparator 216 determines that the amplitude of the ultrasonic signal on line 230 is larger than the height (threshold) of the bar represented by a signal on line 238, it delivers a square pulse and the AND-gate 217 is open as long as the square pulse from the flip-flop 211 is present on line 236, i.e. when the echo signal to be represented is larger than the bar height and falls within the width of the gate bar. In that case, the flip-flop 218 connected to the AND-gate 217 is switched and applies a signal to the line 241 which may be used to trigger an alarm, e.g. a horn or buzzer. The display of the ultrasonic signal and the triggering or the alarm occur at the same time, provided that the echo signal is larger than the set height and falls within the width limits. The flip-flop 218 is reset by a signal from the microprocessor received on the line 242. The above-described circuit may be used as a peak detector circuit by causing the microprocessor to follow a program of gradually increasing the threshold until the output of the AND-gate 217 no longer indicates the existence of an echo signal; i.e., the microprocessor 28 automatically increases the gate threshold fed to the converter 214 in step-wise fashion while the comparator 216 performs successive comparisons so that the maximum value of the echo signal may be determined.

If however, the switches $S_1$ and $S_2$ are in the position shown in dashed lines in Fig. 8, the CRT displays the gate-bar. This is accomplished in that the microprocessor applies a trigger signal to the counter 210 via the line 243 and also to the trigger generator 26. The D—A converter 214 applies a bar height signal to the Y-deflection plates of the CRT, thereby positioning the bar at the correct height on the screen while the square pulse 237 on the output line 236 of the flip-flop 211 which defines the horizontal position of the gate-bar is passed through the switch $S_2$ to the cathode beam control electrode of the CRT (Z-input) to enable the beam current which makes the gate bar visible on the screen.

Fig. 9 is a timing diagram which illustrates the timing of the various signals and events. Fig. 9a shows three successive trigger pulses. The ultrasonic display occurs between the first and second trigger pulses. If necesary, the microprocessor calculates the new pulse count number for the gate start, $N_{MA}$ and the number $N_{MB}$ for the gate width. These numbers are loaded into the register 29 followed by the monitoring and indicating of the occurrence of an echo signal within the defined gate bar with an amplitude exceeding the vertical position of the bar. After the switches $S_1$ and $S_2$ have switched, the gate bar is displayed between the second and third trigger pulses. In the next cycle, the ultrasonic echo signal is displayed again, a.s.o. If a second gate bar is to be displayed, it has been found to be suitable to permit an intervening display of an echo signal to maintain adequate brightness of the echo signal. Due to the fact that the individual sequential displays follow one another with great rapidity, an observer perceives all events simultaneously.

Fig. 9b shows the signal applied to the vertical (Y) deflection plates. Between the first and second trigger pulse the figure shows the ultrasonic signal which may be received during a test while the voltage corresponding to the bar height is shown between trigger pulses two and three. Fig. 9c shows the horizontal deflection voltage and it will be seen that, after the first trigger pulse, a holding time $t_{BA}$ is permitted to elapse by the trigger delay circuit 27 whereafter the trigger generator 26 is actuated and

generates the sawtooth waveform during the time $t_{BB}$.

The beam-enabling voltage applied to the Z-input of the CRT is generated only during the time $t_{BB}$ and the waveform of the echo signal is visible only during that time. Fig. 9 shows this Z-control pulse. Fig. 9e illustrates the rectangular signal 237 which occurs at the output 236 of the flip-flop 211 and which is released after a time $t_{MA}$ for a period equal to the width of the gate bar. This signal is applied to the AND gate 217 and causes the switchover of the flip-flop 216 if the comparator 216 senses that the gate threshold is exceeded, permitting the activation of an alarm or recording device via line 241.

While the gate bar is being displayed, i.e. during the time period between the trigger pulses two and three, the vertical (Y) defection plates of the CRT receive the bar height signal supplied by the converter 214 which is shown in Fig. 9b, while the horizontal (X) deflection plates receive the sawtooth voltage supplied by the trigger generator 26 which has the same traversing (rise) time $t_{BN}$ as the traversing time $t_{BB}$ of the imaging beam. These relations are shown in Fig. 9c. During the time $t_{MB}$ in the diagram of Fig. 9d, the screen displays the gate bar because of the presence of the Z-control signal from the flip-flop 211, shown in Fig. 9e. The time $t'_{MA}$ shown in Fig. 9e indicates the time span between the onset of the sawtooth voltage and the triggering of the signal for representing the gate bar, i.e. the onset of the gate bar display. Accordingly, the pulse count number for the start of the bar display is

$$N'_{MA} = N_{MA} - N_{BA}.$$

The advantage of advancing the gate bar start by the time $t_{BA}$ resides in the fact that more time is available for further processing and that the next transmitter trigger pulse can be released sooner.

The gate bar trigger pulse occurring on line 232 need not actuate the transmitter 21 because ultrasonic echo signals received during that time are not processed anyway.

Fig. 10 shows a preferred circuit for generating the pulses $I_1$ and $I_2$ related, respectively, to the onset and termination of the gate bar. As in Fig. 8, the microprocessor 28 is connected via the line 231 to the register 29 which, in turn, is connected to the counter 210. The register 29 may be embodied, for example, as a counter of the commercial type SN 74C 374; the counter 210 may be a binary down-counting counter, composed, for example, of two commercial counters of the type SN 74 191, connected in series.

One input of an AND-gate 220 is connected to a clock generator 213 and receives a signal train of frequency $f_0$ while the other input is coupled to the output of a flip-flop 221. Depending on the position of the switch $S_3$, either the full frequency $f_0$ or the frequency $f_0/10$ is applied to the counter 210 via line 244. The switch $S_3$ is controlled by a flip-flop 223. The microprocessor 28 applies control signals to various points, i.e. to the control input 245 of the register, the input 246 of an OR-gate 219 which controls the input 247 of the counter 210, to the control inputs 248 and 249 of the flip-flop 221 and to the control inputs 250 and 251 of the flip-flop 223.

A control signal at the control input 245 of the register 29 causes the pulse count number $N_{MA}$, related to the onset of the gate bar, to be loaded into the register 29. Subsequently, the control signal at the input 246 of the OR-gate 219 causes loading of the pulse count number $N_{MA}$ in the counter 210. Finally, the pulse count number $N_{MB}$, related to the width of the gate bar, is loaded into the register. This number is available for processing at the up-count inputs 248 of the counter 210.

A control signal applied by the microprocessor to the input 250 or 251 of the flip-flop 223 determines whether the switch $S_3$ passes the full frequency $f_0$ or the diminished frequency $f_0/10$ to the counter 210.

The counting process is initiated by a trigger signal supplied by the microprocessor to the input 248 of the flip-flop 221. The content of the counter 210, i.e., the pulse count number $N_{MA}$, related to the onset of the gate bar, is counted down. When the count has reached zero, a pulse on line 234 is passed to the flip-flop 211 (Fig. 8) and also to the other input 252 of the OR-gate 219, so that the pulse number $N_{MB}$, related to the gate width, is transferred to the counter 210. The clock pulses arriving on line 244 are used to count this number down as well and when the count reaches zero, the pulse $I_2$ signifies the termination of the gate bar.

It is possible to perform the counting of the numbers related to onset and the width of the gate bar with different frequencies. That will be necessary if one of these numbers exceeds the capacity of the counter 210. One input of the flip-flop 223 which actuates the switch $S_3$ is connected to the output of an AND-gate 224 whose one input is connected to the output of a further flip-flop 225 that is set by a pulse arriving from the microprocessor on line 253 and reset on line 254. The other input of the AND-gate 224 is connected via the line 255 to the output line 234 of the counter 210. In this way, after the time before the onset of the gate bar has expired, the pulse $I_1$ on the line 255 can be used to flip the switch $S_3$ if an appropriate control signal is present at the set-input 253 of the flip-flop 225.

One significant advantage of the above described circuit is that the dimensions of the gate bar can be entered directly on the keyboard in units of length (mm or inch) and will cause the correct positioning of the gate bar on the screen. All the relevant data and parameters, such as the delay distances, the speed of sound in the testing head and in the test object etc. are taken into account by the microprocessor during the calculation of the corresponding pulse numbers. Accordingly, it is no longer necessary to set the parameters of the gate bar with analog devices, e.g. potentiometers, while the final

calibration must be made manually.

Fig. 11 is a block diagram of another embodiment of the ultrasonic testing instrument shown in Fig. 5, including a number of additional elements. The microprocessor 31 of Fig. 11 includes a computer unit 32 and several memories i.e. a ROM 33, a RAM 34 and a Random Access Read Out Memory 35 connected to an internal bus 36. The microprocessor 31 is connected to the external system of buses via an Input/Output circuit 37. The external buses include an 8-line data bus 340, an 8-line control bus 341 and additional lines 342 and 343 which will be further explained below. The microprocessor is preferably of the type Z80, for example as manufactured by MOSTEK and marketed under the designation Z80 Microprocessor. The circuit of Fig. 11 also includes again a transmitter 315 for producing the ultrasonic drive signal, the probe 316 for transmitting the ultrasonic signal into a test object 318, as well as for receiving the echo signals which pass to an amplifier 317. As already mentioned, the transmitter 315 is activated by receipt of a trigger pulse on the line 344; it sends a transmission pulse to the probe 316 via the line 345, causing the transmission of ultrasonic energy into the test object 318. The transmission trigger pulse is produced in the microprocessor 31 and passes to the trigger delay circuit 38 via the I/O circuit 37 and the data and control buses 340, 341. After a delay time, the circuit 38 produces the transmission trigger pulse. The ultrasonic pulse transmitted into the test object may encounter structural faults which cause echoes that are reflected back to the probe 316 where the echoes are converted to electrical signals which are amplified in the receiver/amplifier 317. The amplified echo signal is provided to the switch S which, when in position A, transmits the signal to the vertical (Y) deflection plates of the CRT.

The horizontal (X) deflection plates of the CRT 320 provide the time base of the display and are connected to the output of an amplifier 321 which is driven by a trigger generator 39. A control circuit 310 provides the necessary beam control signal (Z-control) to a Z-axis amplifier 322; this signal is provided during the time during which the sawtooth voltage occurs. The microprocessor is also connected to receive input from a keyboard 313 which serves to enter desired operating parameters, and a recording device, e.g. a tape recorder 314 for storing the test data. Still further connected to the microprocessor is a screen-writing circuit 311 which can feed text signals to the CRT when the switch S is in the position B and a gate-circuits 312 that generates the aforementioned gate-bar. A clock 232 delivers timing pulses to the trigger delay circuit 38 and to the gate circuit 312. The various lateral connections among the elements 38, 39, 310, 311 and 312 are designated 352—355. The switch S is controlled by the control unit 310 over the line 356.

Fig. 12 is a front elevational view of an ultrasonic testing instrument according to the invention which houses the circuitry of Fig. 11. The front panel of the instrument includes a CRT 324 and four groups of data entry devices $T_1$—$T_4$. Group $T_3$ also includes a rotary knob 325 and a multiplier button 326. The various key switches are of commercial origin and are available, for example, from the firm Datanetics/Knitter. These key switches must be equipped with suitable coding circuits, for example matrix-type coding circuits so that an application of a given key produces an acceptable binary datum for the microprocessor.

The keyboard group $T_1$ includes three keys T, A and A′ which provide the basic mode of representation of the instrument. Depression of the key T causes the instrument to be usable in the manner of a data terminal, i.e., printed text is placed on the screen 324 in a manner yet to be described. Actuation of the key A causes the well-known A-representation which provides for the display of echo signals from faults in the test object and actuation of the key A′ provides for display of the A-type with simultaneous display of a line of text. The key group $T_2$ includes four keys related to basic functions, namely a key BS for screen data, a key PK for probes data, a key MA for materials data and a key MO for gate data. Actuation of any of these keys provides data entry access to the respective memories in the microprocessor 31. The key group $T_2$ also includes the keys C and C′ which can be used to move a cursor vertically (using key C) or horizontally (using key C′). If the cursor is placed on a particular line or column in the display, the keys in group $T_3$ provide access to the memory location related to the cursor position.

The key group $T_4$ consists of two special function keys, a key AS, which, when actuated, provides for storage of the A-image representation and a key LZ which permits measurement of the propagation time of the ultrasonic signal.

Fig. 13 is an example of the text data which may be displayed on the screen upon actuation of the key T in the key group $T_1$ and actuation of the key MO in the key group $T_2$. The data displayed are those which had previously been entered into memory by the keys in the group $T_3$. The display includes a movable cursor, an unchanging explanatory text, variable data taken from memory and changable by application of the appropriate keys of group $T_3$ and suitable dimensions.

If the key MO is actuated, the text and the dimensions are read out of the ROM 33 into the appropriate section of the RAM 35. The changeable parts of the display are taken from the RAM 34 and placed in the corresponding sections of the Read-out RAM 35. By placing the cursor at the proper location with the aid of keys C and C′ and actuating the keys in the group $T_3$, the stored data may be altered at will and is then displayed on the screen. The complete text is continuously displayed until a different set of keys is actuated.

When the entry of the operating data is complete, i.e., when the various parameters relating to the

CRT, the probe (delay distance, velocity of sound etc), the test object (velocity of sound, etc.) and the gate-bar (onset, width, threshold, alarm and peak detector) have been entered by use of the various keys in group $T_2$, the key A is depressed, whereupon the microprocessor 31 begins to compute from these data the required count numbers N for the trigger delay circuit 38, the trigger generator 39 and the gate 312 in the manner already described above.

Subsequently, the screen displays the A-image corresponding to the workpiece, i.e. the echoes reflected from inhomogeneities within the workpiece and within the selected depth range. The adjustments required to account for the various characteristics of the probe, the material of the workpiece and the characteristics of the CRT are all automatically taken into consideration so that no further calibration is required. During this display, the switch S of Fig. 11 is connected to the contact A.

As already explained, when the holding time $t_{BA}$ computed by the microprocessor 31 has expired (see Fig. 9), the trigger delay circuit 38 sends a pulse over the line 352 (Fig. 11) which triggers the generation of the sawtooth voltage with a forward trace sweep time $t_{BB}$ also as computed by the microprocessor. The sawtooth voltage is applied to the horizontal (X) deflection plates of the cathode ray tube 320. The sawtooth voltage is also used to generate the intensity control signal via the line 353 by causing the control unit 310 to produce a rectangular pulse for the duration of the sweep time of the sawtooth, which pulse is applied to the Z-control inputs of the CRT 320.

If the key A' is depressed instead of the key A, i.e. if it is desired to display the signal and and the text simultaneously, a line of text appears on the screen in addition to the echo signals, namely the line to which the cursor points. This condition is shown in Fig. 15. In this mode of display, the switch S of Fig. 11 alternates between the contacts A and B. In the position A, in which it resides for approx. 18 ms, the screen depicts the echo signal one or more times. In the position B, in which the switch resides for approx. 2 ms, the line of text is displayed. Due to the relatively short dwell times and the rapid repetition rate, the observer perceives a composite display.

Fig. 15 is a representation of a display including the gate bar in the position it occupies when the following keys are actuated: in the key group $T_2$ the key MO is pushed causing the display of the "gate" function to appear as shown in Fig. 13. The cursor is then positioned to the line marked "display" and the key marked "YES" in the key group $T_3$ turns on the gate. When the key A or A' is pressed, the gate bar appears. In the case of actuation of key A', the screen shows the ultrasonic echo for 18 ms and subsequently the gate bar and a line of text for approx. 2 ms.

Fig. 14 is a block diagram of a portion of a circuit similar to that of Fig. 11 but including some additions. The additions comprise a transit time meter 327, an A-image converter 328 and an interface unit 329 for connecting the instrument to an external processing device, not shown. In this manner, the ultrasonic pattern can be presented additionally to the A-image converter 328 where it is converted into digital values which can be either stored in the RAM 34 of the microprocessor or in a recording device 314. This process is initiated by pressing the key AS in the key group $T_4$. The screen then shows the text line "Recording" and when the key "YES" in key group $T_3$ is pressed, the A-image is recorded in the memory. When the key LZ is pressed, the instrument measures the transit time of the ultrasonic signals in a known manner by means of the metering circuit 327 which receives the ultrasonic signal from the line 347 and the clock frequency from line 351.

As shown in Fig. 16, the writing unit 311 (Fig. 11) comprises basically two modules. The first module is responsible for the vertical (Y) deflection of the cathode ray and consists of an intermediate memory 330 connected to the data bus 340 of the microprocessor, a digital-analog converter 331 and an amplifier 332 whose output is connected to the line 350 and which, as shown in Fig. 11, passes through the switch S and the amplifier 319 to the Y-deflection plates of the CRT.

The second module consists of a second intermediate memory 333, also connected to the data bus 340, a shift register 334 and an electronic switch 335 whose output is connected to the line 354 in Fig. 11; this line is connected to the control unit 310 which controls the Z-input of the CRT, i.e., the intensity of the beam. The transfer commands for the two intermediate memories 330 and 333 pass from the control bus 341 through a command decoder 336 to the inputs 360 and 361, respectively, of the two memories. The input 362 of the shift register 334 is connected to the clock generator 323 shown in Fig. 11 via the line 351. The decoder 336 can also pass a trigger pulse to the trigger generator 39 over the line 365 to cause the latter to initiate the sawtooth signal. Finally, the decoder 336 is connected through lines 363 and 364 to the control lines 342 and 343, respectively, of the microprocessor.

The process of writing a line of text on the CRT is as follows: If, for example, the key MA for material data is depressed, the microprocessor 31 transmits the appropriate material data to the RAM 35 and the digital information required to write the first line of text passes over the data bus 340 to the intermediate memory 330; this information serves for controlling the Y-deflection of the beam. For this purpose, the intermediate memory 330 is activated by the control bus 341 via the control decoder 336 provided that a "Ready" signal from the I/O circuit 37 and delivered to the line 342 is present at the input 364 of the decoder 336. A strobe signal is then returned through lines 363 and 343 to the I/O circuit 37. Subsequently, the data stored in the intermediate memory 330 stand ready at the D/A converter 331 and the analog value produced there is amplified in the amplifier 332 to a voltage $U_Y$ which passes over the line 350 and the switch S and which, after further amplification in the amplifier

319, is applied to the vertical (Y) deflection plates of the CRT, causing the still dark electron beam to be aimed at the upper left corner of the screen.

Subsequently, the first brightness control byte is taken from the selection RAM 35 and is loaded into the intermediate memory 33 via the data bus 340 under the control of the control bus 341 and with the aid of the decoder 336. This digital value is transferred to the register 334 which operates as a parallel-series converter and which transfers the signals for a bright beam H and a dark beam L to the switch 335 in the rhythm of the clock frequency. This frequency on line 351 is started by the clock generator 323 only after the trigger generator 39 has received the trigger pulse for starting the sawtooth voltage from the decoder 336 via the line 351. Under the influence of the sawtooth waveform, the electron beam travels from left to right along the upper image line while being modulated in intensity by the brightness control signals being taken out of the shift register 334 so as to cause illumination of the image points which constitute the line of text. While the shift register 334 is emptied, the next intensity control byte required for the continuation of the text line is prepared for uninterrupted transfer to the shift register 334. After the passage of sixteen intensity control bytes, the electron beam has arrived at the right edge of the screen, i.e., at the end of the first image line of the first line of characters. During the fly-back of the beam, no intensity control bytes reach the line 354 and the screen remains dark. Subsequently, the intermediate memory 330, the converter 331 and the amplifier 332 reduce the vertical deflection voltage $U_Y$ by an amount equal to one image line of a line of characters so that the next sixteen intensity control bytes for forming the second image line of the first line of characters can be transmitted.

Each line of text or characters is composed of five image lines so that, after five complete writing processes, the first line of text is fully formed. At that time, the microprocessor shifts the beam downward by a distance equal to three image lines and starts the generation of the second line of characters. In a manner similar to that of a TV scan, the lines of text are composed by sequential horizontal scans. The total amount of textual information may consist of ten lines of text with twenty-one characters per line, in the exemplary embodiment described here.

As already noted, each line of characters is composed of five lines of image points; after ten lines of text have been written, the electron beam is positioned in the lower right-hand corner of the screen.

The gate bar shown in Fig. 15 is also generated by the circuit of Fig. 16. The vertical position, i.e. the height, of the gate bar, which constitutes a threshold level, is formed by the intermediate memory 330, the converter 331 and the amplifier 332 and is applied to the vertical (Y) deflection plates of the CRT. The operator-selected values for the start and width of the gate bar, entered by pressing the key MO and the appropriate keys in group $T_3$ (Fig. 12) are used by the microprocessor 31 to generate corresponding traversing times for the electron beam so that the beam may be intensity-modulated in the manner required to place the gate bar at the correct position on the screen.

The ultrasonic test instrument described hereinabove is characterized by compact construction and convenient operation. It may be constructed as a portable unit capable of universal use. The internal computational and other features which are part of this invention relieve the operator of many of the adjustments and calibrations which are necessary when using known instruments of this general type. A particularly advantageous feature of the present invention is that the cathode ray screen which is normally present for the display of the echo signal information is used, additionally, for the presentation of other information.

The screen is used, in addition to the display of the echo signal, for presenting both selected and computed data, displaying legends and dimensions of these data, and displaying text and a monitor signal gate bar related to the region of interest within the workpiece. All of these displays may be made at the same time as the display of the echo signal. The data entry keys are grouped in convenient fields related to function in a way which makes possible a compact and practical construction.

The foregoing description and illustrations relate to preferred exemplary embodiments and variants of the invention. These embodiments are to be regarded as serving the purpose of explanation and not limitation. Various other embodiments, variants and constructions may be made and features of one embodiment used with another, all within the spirit and scope of the invention, the latter of which is defined by the appended claims.

CLAIMS

1. A circuit for generating a sawtooth voltage, comprising:

a) A sawtooth generator including a voltage source and at least one capacitor, having an output which carries a sawtooth voltage having a time characteristic (slope, traversing time, rise/fall time) which depends on the capacitance of said capacitor and on the magnitude of the charging current to said capacitor;

b) a counting circuit (13) for determining the traversing time of the sawtooth voltage generated by said sawtooth generator (11);

c) a data-entry keyboard (17) for setting desired values at least of the time characteristics of the sawtooth voltage; and

d) a comparator circuit (15) which produces an output signal in dependence on the difference

between the traversing times of the desired sawtooth voltage and the actual sawtooth voltage and including means for using said output signal to adjust the sawtooth voltage produced by the sawtooth generator to the desired value.

2. A circuit according to claim 1, including a bistable element (121) connected to said sawtooth generator for triggering the onset of the sawtooth voltage in a first state thereof and for terminating the sawtooth voltage in a second state thereof.

3. A circuit according to claim 2, including a threshold circuit (12) connected to the output of said sawtooth generator (11) and having an output connected to said bistable element (121) for placing said bistable element (121) in its second state when the amplitude of the sawtooth voltage generated by said sawtooth generator (11) equals the threshold set in said threshold circuit (12).

4. A circuit according to claim 2 wherein said counting circuit (13) is connected to said bistable element (12) and to a clock generator (14) and whereby, when said bistable element (121) is in its first state, said counting circuit (13) counts the pulses received from said clock generator (14).

5. A circuit according to claim 1, further comprising a cathode ray tube (112) having horizontal deflection plates (111) serving for time-dependent deflection of an electron beam, said deflection plates (111) being connected to the output (107) of said sawtooth generator (11).

6. A circuit for generating a sawtooth voltage, comprising:

a) a sawtooth generator (11) including a voltage source ($U_o$) and at least one capacitor (C) and having an output line (141) which carries a sawtooth voltage the time characteristic of which (traversing time, rise/fall time) depends on the capacitance of said capacitor (C) and including means for supplying a defined charging current to said capacitor;

b) a counting circuit (13) for determining the traversing time of the sawtooth voltage generated by said sawtooth generator;

c) a data-entry keyboard (17) for setting desired values of at least the time characteristics of the sawtooth voltage;

d) a microprocessor (114) including a program memory, connected to said sawtooth generator, for generating a definite sequence of sawtooth waveforms of different time characteristics (traversing time) and including memory means for storing the traversing times of sequential sawtooth waveforms and further including a computing circuit for comparing the preset nominal traversing time with the stored traversing times and for generating an output signal which causes the sawtooth volgate generated by said sawtooth generator to be adjusted so that the traversing time will correspond to the desired value.

7. A circuit according to claim 6, wherein said sawtooth generator includes a plurality of capacitors (C) and a plurality of switches (S); whereby each switch can couple one of said capacitors to said voltage source ($U_o$).

8. A circuit according to claim 7 wherein said microprocessor is programmed to activate all of the switches (S) in said sawtooth generator sequentially and to store in memory the traversing times of the resulting sawtooth voltage and wherein said computing circuit selects the traversing time most nearly equal to the desired value and activates the combination of switches (S) which results in that traversing time.

9. A circuit according to claim 9, further including a resistor ($R_o$) connected to said at least one capacitor (C) and an operational amplifier (115) for producing a defined charging current (I) for charging said at least one capacitor (C).

10. A circuit according to claim 9, wherein said microprocessor includes means for applying a control voltage ($U_E$) to one input of said operational amplifier (115), the magnitude of which depends on the difference between the desired and the actual traversing times of the sawtooth voltage.

11. A circuit according to claim 6, wherein

a) said sawtooth generator includes a plurality of capacitors and a voltage source connected across a switch to one electrode of each one of said capacitors, the other electrode of each one of said capacitors being connected to an output line (141) and a resistor ($R_o$) and including an operational amplifier (115) for regulating the charging current supplied to the capacitors connected to said voltage source, said output line (141) being connectable to said voltage source ($U_o$) across a further switch ($S_8$) which, when open, permits the charging condition of said capacitors to change and produce said sawtooth voltage and which, when closed, applies the voltage ($U_o$) to both electrodes of each of said capacitors, thereby terminating the generation of the sawtooth voltage;

b) the microprocessor includes means and programs for sequentially connecting the switches (S) of said sawtooth generator and storing the resulting traversing times in memory and further including a computing circuit for comparing the preset nominal traversing time with the stored traversing times and for generating an output signal which causes the sawtooth voltage generated by said sawtooth generator to be adjusted so that the traversing time will correspond to the desired value.

12. A circuit according to claim 11, wherein all switches are embodied as semi-conductor switches.

13. A circuit according to claim 11, including a bistable element (121) connected to said counting circuit (13) for triggering the onset of the sawtooth voltage in a first state thereof and for terminating

the sawtooth voltage in a second state thereof.

14. A circuit according to claim 11, further including a threshold circuit (12) connected to said bistable element (121) and to the output line of said sawtooth generator (11) and for placing said bistable element (121) in its second state when the amplitude of the sawtooth voltage equals the preset threshold voltage.

15. A circuit according to claim 11, wherein said counting circuit is connected to said bistable element and to a clock generator; whereby said counting circuit counts pulses from the clock generator while said bistable element is in its first state.

16. A circuit according to claim 11, further comprising a cathode ray tube having deflection plates for time-dependent deflection of the electron beam, said deflection plates being connected to the output of said sawtooth generator.

17. An apparatus for displaying an ultrasonic signal on the screen of a cathode ray tube; comprising:

a) a testing head (129) for radiating ultrasonic energy into a test object and receiving reflected echoes of said ultrasonic energy reflected from inhomogeneities in said test object, said echoes being converted to electrical signals applied to the vertical (Y) deflection plates of said cathode ray tube (112);

b) a trigger generator (124) for generating a sawtooth voltage which is applied to the horizontal (X) deflection plates of said cathode ray tube, the final amplitude of said sawtooth voltage and the traversing time (rise/fall time) being pre-defined;

c) a data entry keyboard (17) for setting a desired image region in units of length (penetration) within said test object and for setting characteristic values relating to the material of the test object and the construction of the testing head; and

d) a microprocessor (114), having memories for storing the values set on the keyboard (17) and including a computing unit for computing the traversing time ($t_H$) corresponding to the desired imaging region within the test object and for computing the trigger delay time ($t_{KV}$) which defines the onset of the traversing time after the emission of the ultrasonic signal.

18. An apparatus according to claim 17, further comprising:

means in said microprocessor for generating an output signal based on the difference between the computed and actual traversing times of the sawtooth voltage and means for using said output signal to adjust the traversing time of the actual sawtooth voltage to the computed value;

e) a first counting circuit (13) for determining the traversing time of the sawtooth which defines the width of the image region; and

f) a second counting circuit (134) for determining the trigger delay time which defines the onset of the imaging region.

19. An apparatus according to claim 18, including a bistable element connected to said trigger generator for initiating the onset of said sawtooth voltage in its first state and for terminating said sawtooth voltage in its second state.

20. An apparatus according to claim 19, wherein said first counting circuit is connected to said bistable element and to a clock generator for counting the pulses from said clock generator while said bistable element is in its first state.

21. An apparatus according to claim 19, including a threshold circuit connected to the output of the trigger generator for placing said bistable element in its second state when the amplitude of the sawtooth voltage equals the threshold voltage.

22. An apparatus according to claim 20, further comprising a trigger delay circuit (125) which contains said second counting circuit (134), said delay circuit (125) being connected to said clock generator (14) and to said microprocessor and wherein said second counting circuit (134) counts the pulses from said pulse generator during the trigger delay time ($t_{KV}$) computed by said microprocessor and generates an output pulse upon termination of the count which triggers the trigger generator.

23. An apparatus for displaying an ultrasonic signal on the screen of a cathode ray tube, comprising:

a) a testing head (22) for radiating an ultrasonic signal into a test object and for receiving echo signals reflected from inhomogeneities in said test object and means for converting said echo signals into electrical signals which are applied to the vertical (Y) deflection plates of said cathode ray tube;

b) a trigger generator (26) for generating a sawtooth voltage applied to the horizontal (X) deflection plates of the cathode ray tube for time-dependent deflection of the electron beam, wherein the final amplitude and the traversing time of the sawtooth which defines a given image region in the test object are preselected values;

c) a data entry keyboard (215) for setting a desired imaging field in units of length and for setting the parameters of a detection window in units of length, said detection window serving to monitor and indicate the occurrence of echo signals within a predetermined region within the imaging field in the test object and further for setting characteristic values relating to the material of the test object and the construction of the testing head;

d) a microprocessor (28) including memory means for storing the parameters set on the keyboard

and a computing circuit for computing the traversing time ($t_H$) which defines the ultrasonic imaging region within the test object and for computing the trigger delay time ($t_{KV}$) which defines the delay between the emission of ultrasonic energy and the onset of the traversing time and further for computing the time ($t_{MB}$) which defines the width of the detection window and the time ($t_{MA}$) which defines the onset of the detection window subsequent to the emission of the ultrasonic signal.

24. An apparatus according to claim 23, wherein:
said trigger generator (26) includes a voltage source and at least one capacitor and has an output line on which appears said sawtooth voltage, the time characteristic of which depends on the capacitance of the capacitor and on the charging current thereof; and wherein:
said microprocessor (28) includes means for generating an output signal which depends on the difference between the traversing times of the computed and the actual sawtooth voltages and means for using said output signal to adjust the sawtooth voltage generated by the trigger generator so that its traversing time is equal to the computed value;
and further comprising:

d) a first counting circuit within the trigger generator (26) for determining the traversing time of the sawtooth voltage generated by the trigger generator which defines the width of the imaging region;
f) a second counting circuit in the trigger delay circuit (27) for determining the trigger delay time which defines the onset of the imaging region;
g) a third counting circuit (210) for supplying a first pulse after counting out the time ($t_{MA}$) which elapses between the emission of the ultrasonic signal and the onset of the detection window and for supplying a second pulse after counting out the time ($t_{MB}$) which defines the width of the detection window, said first and second pulses being supplied to a bistable element (211); and
h) a switch ($S_2$) which switches the signal (237) put out by said bistable element (211) alternately to a circuit for monitoring and indicating an echo signal occurring within the detection window while the trigger generator (26) generates a sawtooth voltage and to the intensity control input (Z-input) of the cathode ray tube to control the imaging of the detection window on the screen.

25. An apparatus according to claim 24, wherein said third counting circuit (210) is connected to the microprocessor via a register (29) which transfers the pulse count number ($N_{MA}$) defining the onset of the detection window to the counter (210) and which then stores the pulse count number ($N_{MB}$) defining the width of the detection window, said counting circuit (210) generating a first pulse after countdown of the pulse count number ($N_{MA}$) and a second pulse after transfer of the pulse count number ($N_{MB}$), said first and second pulses serving, respectively, to set and reset a bistable element (211).

26. An apparatus according to claim 25, including a clock generator (213) connectable, selectively, directly to said third counting circuit (210) or via a frequency divider circuit (222); whereby the counter content related to the onset of the detection window and the counter content related to the width of the detection window may be counted out at different frequencies.

27. An apparatus according to claim 24, wherein the circuit for monitoring and indicating an echo signal includes the following elements:

a) a comparator (216) having a first input connected to a line (230) which carries said echo signal and having a second input to which is fed a threshold value related to the amplitude of the detection window, said comparator providing an output signal when the amplitude of the echo signal exceeds the threshold;
b) an AND-gate (217) having a first input to which is applied the signal generated by the bistable element (211) and a second input connected to the output of the comparator (216); and
c) the output of the AND-gate (217) is connected to an indicating device.

28. An apparatus according to claim 27, including a switch ($S_1$) which, alternatingly, connects the echo signal to the vertical (Y) deflection plates of the CRT when the trigger generator supplies a sawtooth voltage and subsequently connects the detection window threshold value to the vertical (Y) deflection plates when the signal (237) produced by the bistable element (211) is being applied to the intensity control input (Z-input) of the CRT for imaging the window on the screen.

29. An apparatus for displaying ultrasonic signals on the screen of a cathode ray tube, comprising:

a) a testing head (316) for radiating ultrasonic signals into a test object and for receiving echo signals reflected from inhomogeneities in the test object, including means for converting said echo signals into electrical signals which are applied to the vertical (Y) deflection plates of the cathode ray tube;
b) a trigger generator (39) for generating a sawtooth voltage applied to the horizontal (X) deflection plates of the CRT for time-dependent deflection of the electron beam, said sawtooth voltage having a defined final amplitude and a traversing time which defines the imaging region within the test object;
c) a data entry keyboard (313) for setting the desired imaging region in the test object directly in units of length and for setting parameters related to the material of the test object and to the construction and type of the testing head;
d) a microprocessor (31) including memory means for storing the parameters set on the keyboard

and a computing circuit for computing the traversing time ($t_H$) which defines the ultrasonic imaging region within the test object and for computing the trigger delay time ($t_{KV}$) which defines the delay between the emission of the ultrasonic signal and the onset of the traversing time and serving further for computing the time ($t_{MB}$) which defines the width of the detection window and the time ($t_{MA}$) which defines the onset of the detection window subsequent to the emission of the ultrasonic signal; and

e) a writing circuit (311) which is connected to the vertical (Y) deflection plates of the cathode ray tube via a switch (S) for producing a line raster signal and intensity modulation signals that cause a screen display of the parameters and values set in the data entry keyboard.

30. An apparatus according to claim 29, wherein said writing circuit (311) includes:

a) a first intermediate memory (330) for storing line height information derived from the microprocessor and a digital-analog converter for converting the contents of the memory to a Y-deflection voltage;

b) a second intermediate memory (333) for storing beam intensity information derived from the microprocessor and a shift register (334)) the output of which is coupled to a switch element (335) for controlling the beam intensity according to the contents of the memory.

31. An apparatus according to claim 30, further including a command decoder (336) for controlling the transfer of information into the first and second intermediate memories according to control data received from the microprocessor.

32. An apparatus according to claim 29, wherein the switch (S) is switchable between two states, one of these states being devoted to the presentation of ultrasonic signals on the screen and the other of these states being devoted to the display of information placed in the apparatus via the keyboard.

33. An apparatus for displaying ultrasonic signals on the screen of a cathode ray tube, comprising:

a) a testing head for radiating an ultrasonic signal into a test object and for receiving echo signals reflected from inhomogeneities within the test object and means for converting said echo signals into electrical signals applied to the vertical (Y) deflection plates of said cathode ray tube;

b) a trigger generator for producing a sawtooth voltage which is applied to the horizontal (X) deflection plates of the cathode ray tube for time-dependent deflection of the electron beam, said sawtooth voltage having a defined final amplitude and a traversing (rise/fall) time which defines the imaging region within the test object;

c) a data entry keyboard including a plurality of input keys ordered in functional groups for the input and binary coding of data related to the desired imaging region, the type and construction of the testing head, the properties of the test material and the representation of the detection window on the screen;

d) a microprocessor including memory means for storing the data entered via the keyboard and a computing unit for computing the traversing time, the trigger delay time, the onset time of the detection window and the width and height of the detection window; and

e) a writing unit (311) for displaying the parameter values entered on the keyboard (313) and stored in memory.

34. An apparatus according to claim 33, wherein the keys on the keyboard (313) are arranged in groups as follows:

a) a first group ($T_1$) including a key for each of the functions
presentation of the ultrasonic signal;
presentation of characters and text;
a mixture of signals and text;

b) a second group ($T_2$) including a key for each of the functions
presenting data related to imaging region;
presenting data related to the testing head;
presenting data related to the material;
presenting data related to the detection window; and

c) a third group ($T_3$) for numerical data entry.

35. An apparatus according to claim 34 wherein the text representation provided by key group two ($T_2$) comprises a section for permanent text, a section for changeable data and a section for dimensions related to the changeable text.

36. An apparatus according to claim 35, including additional keys for positioning a cursor in a desired place on the screen to thereby select the data to be changed.

37. Apparatus as claimed in any preceding claim and constructed and arranged to operate substantially as described with reference to the drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1981. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.